The Journal of Thoracic Surgery

VOL. 21 FEBRUARY, 1951 NO. 2

Original Communications

PNEUMONECTOMY WITH REPLANTATION OF THE LUNG IN THE DOG FOR PHYSIOLOGIC STUDY

ANDRE A. JUVENELLE, M.D., COLEMAN CITRET, M.D., CHARLES E. WILES, JR., M.D., AND JOHN D. STEWART, M.D., BUFFALO, N. Y.

IT IS well known that many problems of lung and cardiopulmonary physiology remain unsolved. So many complex and variable factors are involved in the responses of this system that our knowledge of the subject often is more theoretical than actual. Previous investigators have learned much from section of the hilum of the lung and perfusion of the isolated organ for short periods of time.[1] By similar methods the cardiopulmonary reflexes have been studied in relation to the problem of pulmonary embolus. Little, however, is known about the entity almost universally called bronchospasm. The concept is useful in explaining many phenomena; actually its existence has yet to be proved. In asthma, for example, it has long been postulated that in certain cases a "trigger point" somewhere in the body can be the initiator of an attack. This theory assumes the existence of reflex arcs which must originate in various sensitive areas. These areas may be in relatively remote parts of the body, such as the skin, pelvic organs, etc. The importance of sensitive areas in the lung itself in initiating reflexes must be further clarifield. Attempts to relieve asthma by interrupting the autonomic nerves to the lung logically follow this unproved hypothesis. The uncertainty surrounding the matter is well illustrated by the opposing views of those advocating the various surgical treatments of so-called intractable asthma.

It seemed to us that a complete denervation of the lung, followed by physiologic studies, would be useful in approaching these problems. We thought that a complete denervation of the lung could best be accomplished by precise dissection of all elements of the hilum, severing these elements completely, then reimplanting the lung by direct anastomosis of all structures.

From the Department of Surgery, University of Buffalo Medical School and the Edward J. Meyer Memorial Hospital.

Received for publication July 10, 1950.

TECHNIQUE

The demonstration of the feasibility of the preparation of such an animal is the chief purpose of this report. After several unsuccessful attempts we have succeeded in having a dog survive such an operation. The operation was performed May 26, 1950.* A review of the technical measures involved follows:

Anesthesia.—The method of anesthesia is of prime importance. Preliminary narcosis is achieved with intraperitoneal nembutal. The free communication between the left and right thoraces of the dog demands mechanically controlled alternating pressure anesthesia. Our first attempts were made with the conventional "windshield wiper" type of apparatus, but this proved to be unsatisfactory. Following the report of Dameron and Greene at the April, 1950, meeting of the American Association for Thoracic Surgery,[2] we obtained one of the Burns valve apparatuses, and have found that it greatly facilitates our work, although falling somewhat short of perfection. The machine functions perfectly throughout most of the procedure, delivering an ether-oxygen mixture to an intratracheal tube with an inflatable cuff. It is only during the period of anastomosis of the severed bronchus that supplementary tubing must be introduced into the opposite main bronchus to maintain respiration while the bronchial anastomosis is being done. The operation is a time-consuming one, but is apparently well tolerated with the use of the Burns valve. Intrapericardial 2 per cent procaine is used freely throughout.

Operative technique.—The right chest is opened in the usual manner through the bed of the sixth rib. The azygos vein is clamped, divided, and ligated to facilitate exposure of the hilum. All pulmonary ligamentous structures are then divided, with ligation of minor vessels wherever necessary. The right main bronchus is carefully freed by sharp dissection and meticulous hemostasis back to the bifurcation of the trachea. The bronchus is then divided with a scalpel, and the proximal stump promptly and snugly closed with Allis forceps, allowing respiration to be maintained by the opposite lung. Using the distal bronchial stump for gentle upward traction, the operator proceeds with the dissection of the posterior aspect of the pulmonary artery and veins. In order to obtain sufficient lengths of these structures it is essential that the dissection be carried intrapericardially until (*a*) the trunk of the pulmonary artery is reached, and (*b*) the entrance of the superior and inferior pulmonary veins into the left auricle is demonstrated. Attention is then directed to the anterior aspect of the vessels. The completion of the dissection of the artery offers no further difficulty. In order to visualize the veins fully, however, a plane of cleavage must be developed between the veins and the right auricle. This dissection begins in the pericardial fat alongside the right auricle and proceeds toward the left auricle until the entrance of the veins into that auricle is reached. It should be noted that in the dissection of the veins from the

*In a communication received from Dr. Stewart under date of Oct. 26, 1950, it was stated that the animal was alive and in good health. Pulmonary functional studies were being made on it.—Editor.

auricle the plane of cleavage must be more or less created, since a natural one does not appear to be well defined. When the dissection is correctly done there should be two or three centimeters each of superior and inferior vein between the auricle and the first branchings. Numerous small bleeding vessels will be encountered and must be controlled. It is also easy to enter the thin-walled auricle inadvertently, a complication greatly increasing the difficulty of the procedure.

When the dissection is completed the artery and veins are successively handled in essentially the same manner, the sequence being artery, superior, then inferior pulmonary vein. Each vessel is occluded as near the heart as possible, using a clamp devised by one of us (A. J.), (Fig. 1). This clamp is a modification of the one devised by Freeman[3] for side-to-side vascular anastomosis. It opens at one end so that it may be slipped on and off an intact vessel. It has no long handle, but is controlled by a small thumb screw, thus occupying little space and allowing free access to all sides of the anastomosis.

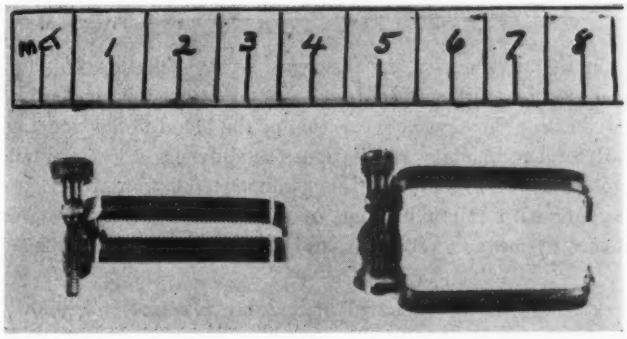


Fig. 1.

Distally the vessel is occluded with a Blalock clamp. After occlusion the vessel is divided and reanastomosis done with 00000 silk by the classical technique of stay sutures converting the round structure to a triangle. Bleeding should be minimal after completion of the anastomoses.

Finally, the bronchus is anastomosed with interrupted sutures of 000 silk.[4,5] It is during this step that the supplementary anesthesia tubing is required. Since the bronchial stump is open, the intratracheal tube cannot be effective and the oxygen-ether under pressure must be introduced through a tube placed in the open bronchus and leading into the opposite main bronchus. As many anastomosing sutures as possible are placed and tied with this tube in place. The remaining sutures are all placed but not tied. The tube is then withdrawn and traction quickly applied to the untied sutures, thereby closing the anastomosis. Anesthesia is immediately resumed through the intratracheal tube. The remaining sutures may then be tied without significant leakage at the line of anastomosis. As much pleuralization of the hilum as possible is then done. There

should be prompt re-expansion of the lung following completion of the bronchial anastomosis. The chest is closed in the usual manner. Penicillin is given for five days postoperatively. Anticoagulants have not been used by us.

DISCUSSION

Following survival of this procedure by an animal in our laboratory, various questions must be answered before the preparation can be put to its fullest use as a tool in physiologic experimentation. Our first efforts have been directed toward verification of the mechanical integrity of the reimplanted lung. Before closure of the chest it was directly observed that the respiratory cycle was grossly normal. The lung was well inflated. Pulsations of the pulmonary artery were seen and felt well beyond the line of anastomosis. A free flow of blood was observed in the veins. Thereafter daily percussion and auscultation of the chest, with frequent fluoroscopy, have shown apparently normal ventilation. On the eighteenth postoperative day angiocardiography was done. The pulmonary arterial tree was well visualized with no apparent difference between the right and left sides. These findings led us to believe in the mechanical integrity of the lung.

The functional integrity, in the sense of oxygenation of the circulating erythrocytes, is more difficult to prove. Studies are planned, and have been begun, to determine the oxygen saturation of the blood under varying conditions of: (*a*) unilateral pulmonary ventilation, (*b*) differing oxygen partial pressures in the two lungs, (*c*) contralateral pneumonectomy, and (*d*) contralateral pneumonectomy with reimplantation of the lung. Attempts will be made to induce reflexes by means of chemical and electrical stimulation of the two lungs separately.

These studies will be repeated at regular intervals to follow the effects of nerve regeneration if and when it occurs.

In the near future an attempt will be made to effect an exchange of lungs between two animals.

The severance of the lung lymphatics, as accomplished by this procedure, has caused no observable effects to this time.

CONCLUSIONS

1. A technique is presented whereby a dog's lung is completely denervated by performing a pneumonectomy and replanting the lung by anastomosis of its bronchus, artery, and veins.

2. At the present writing one animal has survived this operation with apparent mechanical integrity of the lung and is undergoing further study to prove functional integrity. The animal is in good health now, five months after the operation. Serial studies are being carried out to investigate regenerative phenomena.

3. It is hoped that the method will offer a useful tool for the further elucidation of problems of pulmonary physiology.

Note.—The authors wish to express their thanks to Doctors Howard Dayman and E. G. Eschner for their advice and aid in the fields of pulmonary physiology and radiography.

REFERENCES

1. Wiggers, C. J.: Physiology in Health and Disease, ed. 5, Philadelphia, 1949, Lea and Febiger, p. 448.
2. Dameron, J. T., and Greene, D. G.: Use of the Burns Valve as a Simple Respirator for Intrathoracic Surgery in the Dog (Read before the American Association for Thoracic Surgery, April, 1950).
3. Freeman, S.: Studies on ECK Fistulas in Dogs, Surg. Gynec., & Obst. **87**: 735, 1948.
4. Jackson, T. D., Lefkin, P., Tuttle, W., and Hampton, F.: An Experimental Study in Bronchial Anastomosis, J. THORACIC SURG. **18**: 631, 1949.
5. Juvenelle, A. A.: Technique of Tracheo-bronchial Anastomosis and Resection of the Tracheal Bifurcation (Read in discussion before American Association for Thoracic Surgery, April, 1950).

SURGICAL TREATMENT OF THREE CASES OF PLEURAL SARCOMA*

SVEN RAMSTRÖM, M.D., AND HELGE HELLSTEN, M.D.,
GOTHENBURG, SWEDEN

THE pleura consists of endothelium resting upon a thin basal membrane and a subendothelial layer of connective tissue rich in elastic fibers. Of malignant tumors involving the pleural tissue, the endothelioma is the most common. It probably arises from endothelial cells, and is often called a mesothelioma to indicate the mesothelial character of the cells and their ability to form neoplasms of both epithelial and connective tissue (Maximow and Kux). Malignant degeneration of the subendothelial connective tissue is thought to give rise to pleural sarcomas. Microscopically these growth are often round-celled sarcomas, but also spindle-celled sarcomas have been described, and mixed tumors such as fibro-, angio-, chondro-, and fibroxanthosarcomas are common. While certain forms of sarcoma may be operable, the endothelioma is generally inoperable on account of its infiltrative mode of growth.

Judging by the literature, pleural sarcomas are rare. Seydel (1910) found only one pleural sarcoma in 10,000 autopsies. In 1931 Lichtenstein could trace only thirty-one cases in the entire literature. Since that time no collections have been reported.

Lichtenstein divides sarcoma of the pleura clinically into three groups. The first group is characterized by high malignancy and extensive spread over the surface precluding surgery. Hemorrhagic effusion is regular. In the second group the sarcoma is likewise very malignant but of less extensive spread. It is very infiltrative and often invades the tissue of the lungs; hemorrhagic effusion is common. The third group is much more interesting from a surgical point of view, because many of these cases can be treated radically. They are well demarcated and clinically benign. They are as a rule not attended by pleural effusion. However, their microscopic structure is that of a sarcoma. They differ from the tumors of the first two groups in that they do not metastasize and show no tendency to recur.

Lichtenstein assigns eight of his cases to this third group, but only one of them was operated on (Quincke and Garré). Further descriptions of operated

From the Surgical Clinic II, Sahlgren's Hospital.
Received for publication May 22, 1950.

*It is doubtful that these cases should be called sarcoma. It would seem that Stout's name, "localized, benign mesothelioma" is to be preferred.—Editor.

cases of pleural sarcoma have been published by Jacobaeus and Key (one case), Klemperer and Rabin (one case), and Fawcett (one case).

The majority of the cases of pleural sarcoma reported in the literature were not diagnosed before autopsy. In most of them the tumors were extensive and probably assignable to one of Lichtenstein's first two groups (e.g. Klemperer and Rabin, one case; Jacob, Jais, and Alison, one case; McMahon and Mallory, one case), and in these cases surgery would probably have been of no avail even if they had been diagnosed in an early stage. But also well-demarcated pleural sarcomas have been described (e.g. McNamara, Sargent, and Costich, one case) in which the patients had, however, sought aid so late that their general condition was too poor to permit surgical intervention. Stout and Murray have described a tumor similar to ours which they regard as a localized benign pleural mesothelioma. By using tissue culture methods they found that the tumor actually originated from mesothelium.

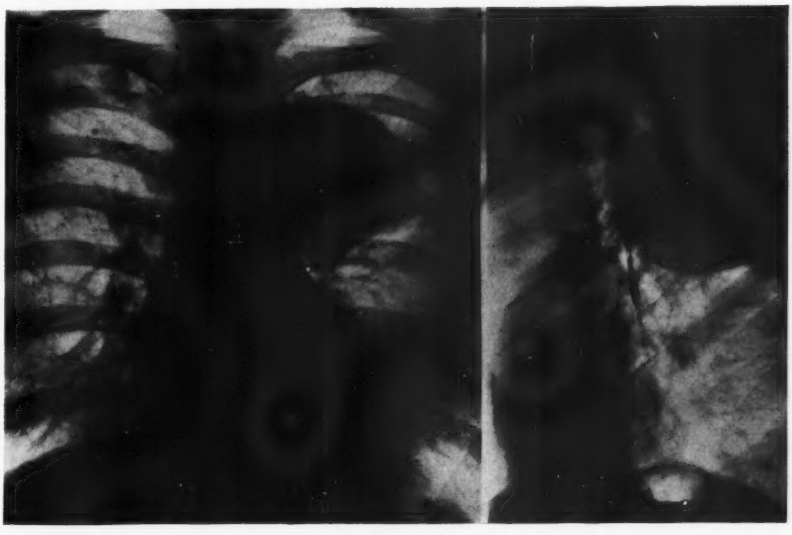


Fig. 1.

An important reason why the number of operated cases is so low as compared with the number observed at autopsy is the lack of symptoms of this type of pleural tumor. The disease is not attended by anemia or cachexia. The growth escapes attention until it has attained such proportions as to compress neighboring organs, when the first symptoms such as dyspnea and signs of circulatory insufficiency will appear. But by then the patients are in such a poor condition, and the tumor has extended so much, that radical surgery is impossible.

We have treated three cases of localized pleural sarcoma at our Clinic. All three were discovered incidentally in the course of routine roentgen ex-

amination. The patients had been given no trouble by the tumors, all of which had attained the size of a fist.

CASE 1.—405/47. A 35-year-old seaman, who had hitherto felt healthy. When the patient was called up for military service, routine roentgen examination revealed an oval, homogeneous, structureless soft tissue density of 8 by 9 by 9 centimeters (Fig. 1) in the left half of the chest. The tumor, the center of which lay on a level with the bifurcation of the trachea, extended up to the lateral wall of the chest on a level with the fifth rib. It was located interlobularly, and it could not be decided whether it had originated from the lung, the hilus, or the thoracic wall. The aorta could be projected by itself. There was no pleural effusion. Bronchography failed to demonstrate any connection with the bronchi.

Fig. 2.

Operation.—Wide thoracotomy after removal of the fifth rib was performed. The pleura was then incised under positive pressure, after which the pressure was gradually released, and the lung collapsed. It was observed that the fist-sized tumor had originated from the lateral thoracic wall, to which it adhered with a rather broad base (4 by 4 centimeters) on a level with the fourth intercostal space in the posterior axillary line. The surface of the growth was covered with smooth, shiny pleura, which could be stripped from the tumor without difficulty. At its base it was adherent to the hemiazygos vein, part of which was therefore removed after ligation on either side of the growth. The tumor had apparently grown from the subpleural connective tissue. No connection could be observed with the intercostal nerve or vessels, all of which were dissected and inspected. After enucleation of the tumor the lung was expanded by positive pressure and the wound closed.

The tumor, which was encapsulated, showed a homogeneous cut surface like the flesh of a fish. Microscopically, it showed the characteristics of a fibrosarcoma with a tendency to develop into a spindle-celled sarcoma (Fig. 2). The postoperative course was unevent-

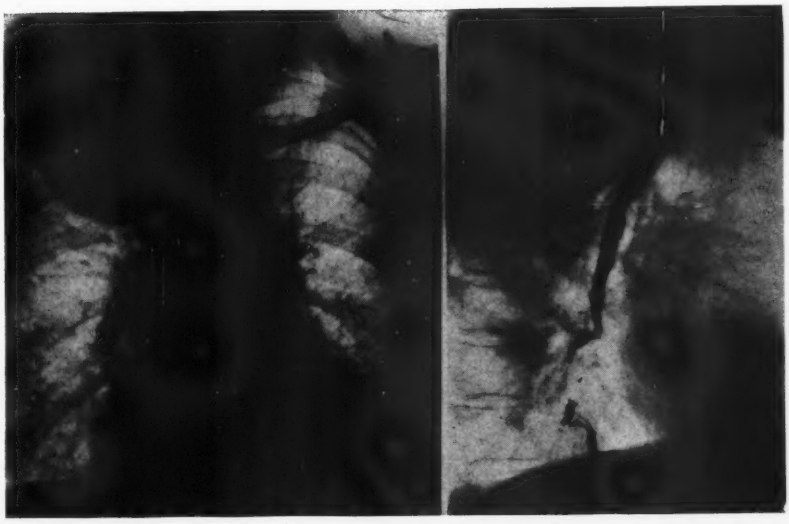


Fig. 3.

Fig. 4.

ful, except for a moderate pleural effusion, which was aspirated on two occasions. The patient received postoperative radiotherapy. At reexamination two and one-half years after the operation he felt well.

CASE 2.—2609/48. In a hitherto healthy 58-year-old woman who was submitted to roentgenography of the heart and lungs on account of hypertonia discovered by chance, the roentgenogram showed a well-defined, round tumor, about 6 centimeters in diameter, in the right half of the thorax (Fig. 3). The upper border of the tumor was on a level with the fourth rib, while the lower border extended down to the seventh rib. No grooving of the ribs could be observed in the roentgenogram, nor could any fluid be discerned in the pleural cavity. A benign tumor, possibly a dermoid cyst, was suspected.

Operation.—Wide thoracotomy after removal of the sixth rib was performed. After the lung had been collapsed, the fist-sized tumor could be inspected. It was almost round, its surface was smooth, and it had a broad base originating from the fourth and fifth intercostal spaces. The tumor was covered with a smooth, shiny, and somewhat thickened pleura, from which it was easily separated. The intercostal nerves and vessels had not been involved by the tumor, which had not invaded the periosteum of the ribs either. The tumor had presumably arisen from the subpleural connective tissue. Here, as in the previous case, enucleation was easy and apparently radical. The lung was expanded by positive pressure, and the wound closed.

Fig. 5.

The encapsulated tumor showed a homogeneous fleshy cut surface, as in the former case. Histologic examination showed a fibrosarcoma rich in cells, with a few myxomatous and xanthomatous cells (Fig. 4). The postoperative course was uneventful, except for moderate pleural effusion which was aspirated and ceased within a few weeks. The patient received postoperative radiotherapy. At reexamination eighteen months after operation the patient felt well.

CASE 3.—4081/49. A 55-year-old woman was submitted to routine roentgen examination of the chest on account of tuberculosis in the family. Roentgenography revealed a roundish, well-demarcated soft-tissue neoplasm 9 by 7 by 8 centimeters in the right half of the thorax, near the vertebras, and extending to the posterior thoracic wall between the fourth and fifth ribs (Fig. 5). The ribs were not grooved. There was no fluid in the pleural cavity.

Operation.—Wide thoracotomy by removal of the fifth rib was performed. The fist-sized tumor was seen immediately lateral to the transverse processes and on a level with the fourth rib. The lung was adherent to the entire surface of the tumor from which it was separated by blunt dissection without any damage to the pulmonary tissue. The tumor had a broad attachment (7 by 7 centimeters) to the posterior thoracic wall. The tumor was lined with a somewhat thickened, but smooth and shiny pleura. After a lambdoid incision in the pleura the tumor could be enucleated. Enucleation presented no difficulties, and it was observed that the tumor had originated from the subpleural connective tissue in the fifth intercostal space. The intercostal nerve and vessels were not involved. The pleural defect left after the removal of the tumor was covered with the above-mentioned lambdoid flap. The lung was expanded with positive pressure, and the incision closed.

The tumor was encapsulated, and its cut surface showed a homogeneous, fleshy appearance with a few almond-sized cysts containing a clear fluid (Fig. 6). Microscopically, it showed the characteristics of xanthofibrosarcoma (Fig. 7). The postoperative course was uneventful, except for a moderate effusion in the pleural cavity, which was aspirated twice. After the wound had healed, radiotherapy was given. At reexamination, three months after operation, the patient was symptom-free.

The three cases described above have much in common. They were all discovered by chance; they were all clinically benign pleural sarcomas (Lichtenstein's third group); they were all fist sized, round, and well demarcated, but with the obvious microscopic structure of sarcomas.

In spite of the proportions they had attained they had given no symptoms, but had all been discovered at routine roentgen examination of the chest, and in middle-aged patients.

In these cases no conclusions can be drawn as to the rate of growth of the tumors. They show, however, that a well-defined density in the roentgenogram ought not to be regarded forthwith as a benign tumor not requiring surgery. We did not resort to exploratory aspiration as a diagnostic aid, because in a few other instances in which the tumor was a dermoid cyst, the cyst content spread outside the tumor, and, if, as in these three cases, the tumors had been malignant, the risks attending exploratory aspiration would probably have been still greater. Neither did we make use of diagnostic pneumothorax, because such a procedure would hardly have influenced the indications for operation. Moreover, we have found pneumothorax to favor serous effusion.

Unless contraindicated for some other reason, all tumors with this x-ray picture indicate surgery, because the tumor might be a sarcoma. In spite of the clinically benign behavior of the sarcomas mentioned above, they grow and thereby compress vital organs, and finally lead to death. In the three cases described above the tumors could be enucleated without difficulty. When carrying out such an operation, however, one must be prepared for lobectomy or pneumonectomy, unless the extrapulmonary location of the tumors can be established at preoperative roentgenography. The tumors respond to radiotherapy, and in the three cases under discussion postoperative radiation was given.

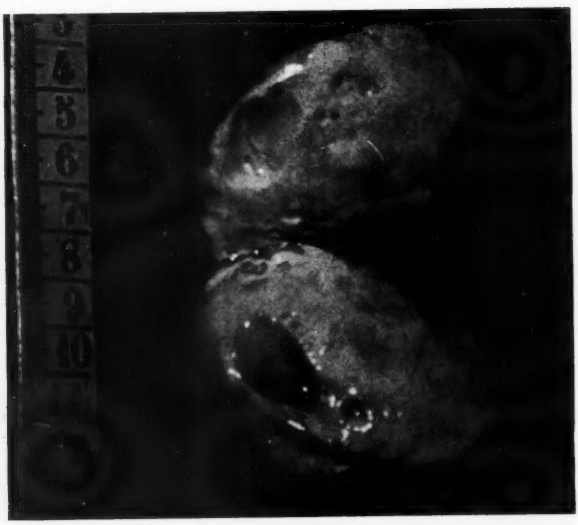


Fig. 6.

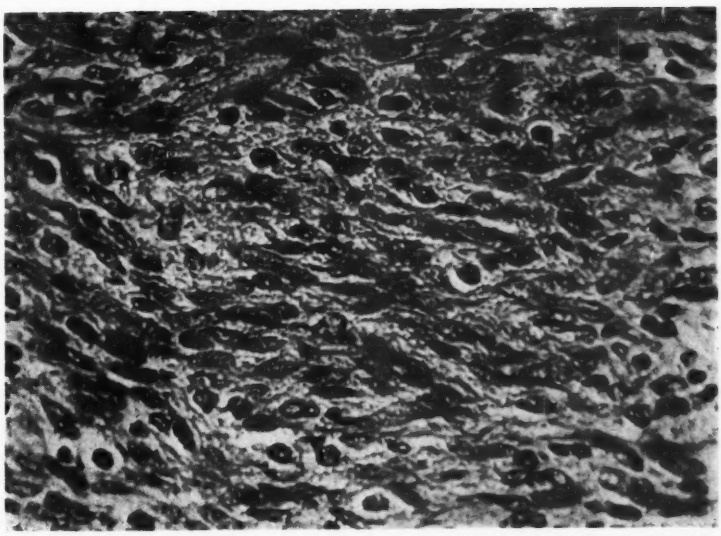


Fig. 7.

SUMMARY

Sarcomas of the pleura are rare. One group of these tumors is of great clinical interest because the growths may be treated successfully by surgery if discovered early enough.

They have the microscopic structure of sarcomas, but do not behave like malignant growths. They are well demarcated, they do not metastasize, nor do they show any tendency to recur. Only some ten cases have apparently been described in the literature, and only a few of these have been operated on.

These sarcomas generally give no symptoms until they have assumed considerable proportions and then compress adjoining vital organs, but by then they are often inoperable on account of the large extent of their growth and the poor condition of the patients.

Three personally operated cases of sarcoma of this type are described. None of them gave symptoms, and all of them were discovered in the course of a routine examination of the chest. They are fist-sized and easy to enucleate.

The importance of surgical treatment of well-defined tumors in the chest is stressed.

REFERENCES

Fawcett, A. W.: Brit. M. J. **2**: 425, 1945.
Jacob, P., Jais, M., and Alison, M.: J. fr. méd. chir. thorac. **3**: 254, 1949.
Jacobaeus, H. C., and Key, E.: Acta chir. Scandinav. **53**: 573, 1920-1921.
Klemperer, P., and Rabin, C. B.: Arch. Path. **11**: 385, 1931.
Kux, E.: Virchows Arch. f. path. Anat. **272**: 650, 1929.
Lichtenstein, H.: Deutsche Ztschr. f. Chir. **233**: 29, 1931.
Maximow, A.: Arch. f. exper. Zellforsch. **4**: 1, 1927 (Ref. Klemperer and Rabin).
MacMahon, H. E., and Mallory, G. K.: Am. J. Path. **4**: 387, 1928.
McNamara, W. L., Sargent, W. E., and Costich, K. J.: Arch. Surg. **55**: 632, 1947.
Quincke and Garré: Lungenchirurgie, ed. 2, Jena. Gustav Fischer, 1912, p. 193.
Seydel: Munchen. med. Wchnschr. 1910, 453 (Ref. Lichtenstein)
Stout, A. P., and Murray, M. R.: Localized Pleural Mesothelioma, Arch. Path. **34**: 951 964, 1942.

RECONSTRUCTION OF DEFECTS OF THE THORACIC WALL WITH TANTALUM MESH GAUZE

(Preliminary Report of Two Cases)

Alexander E. W. Ada, M.D., and Engel P. Hevenor, M.D.*
New York, N. Y.

THE repair of defects of the thoracic wall has been accomplished in various ways, as outlined below. But, we believe that these are the first reported cases in which tantalum mesh gauze has been used. When tumors of the chest wall are radically removed or trauma leaves defects, herniation of the lung may occur unless some firm reconstruction is performed.

Tuffier,[13] in 1891, treated a lung hernia of the second intercostal space by removing the sac and closing the pleura. He gives no definite description of any repair of the outer layers. Volger,[14] in 1898, presented a case of lung hernia near the right border of the sternum, following fracture and displacement of the right third rib. He suggested that an osteoperiosteal flap of the sternum or second or fourth ribs could be made and swung into the defect. Vulpius,[15] in 1900, operated on Volger's patient, and split the second rib and costal cartilage near the sternum into an anterior and posterior half of bone and cartilage. Then he swung the medial end of the anterior split portion down, and attached it to the sternal remnant of the third rib with silver wire. The lateral end remained attached in its normal position. The hernia recurred after one year. Graham,[5] in 1922, treated a cervical lung hernia by packing the region with iodoform gauze and removing the gauze five days later. Montgomery and Lutz,[9] in 1925, repaired a hernia of the fourth anterior interspace by turning a flap of periosteum and perichondrium from the anterior surface of the fifth rib and cartilage into the fourth interspace. An osteocartilagenous flap of the fourth rib was then made by splitting it in two from above downward, and turning it down, hinging it on its periosteum and perichondrium. Goodman,[4] in 1933, repaired a hernia of the fifth interspace by dissecting out the pleural sac, and closing it after the redundant pleura had been removed. Then the anterior periosteum was turned down from the fifth rib and up from the sixth rib, and sutured over the weakness. Winkel,[17] in 1935, wove strips of fascia lata between the ribs or endothoracic fascia to close a weakness in the thoracic wall. Watson and James[16] modified this technique by closing the defects with single, large, free fascia lata grafts. Maurer and Blades,[8] in 1946, used periosteal flaps and ribs cleaned of periosteum, cut across, and swung obliquely down to cover defects. They reported that Paulson had attempted to use a tantalum plate to cover a hernia of the lung, but had abondoned it because of the difficulty of immoblization. Beardsly[1] used tantalum plate in three cases

Received for publication July 17, 1950.
*From the Department of Surgery, St. Luke's Hospital.

when reconstructing the chest wall after resecting large areas. The patients were comfortable, but in the three cases they developed serous drainage from around the plates, and in two cases the serum became purulent. The plates were later removed in all three cases, after there had been a fibrous reaction around them giving stability to the thoracic walls. Campbell[2] reconstructed the entire thickness of the anterior thoracic wall by freeing the latissimus dorsi muscle from its insertion and swinging it up into the defect, and covering the muscle with a free split thickness skin graft. When the skin is involved in the tumor and has to be sacrificed, this method has advantages over the others that have been described. The surface can be epithelialized by a free graft, and dependence is not placed on flaps of skin and subcutaneous tissue, whose survival may be precarious.

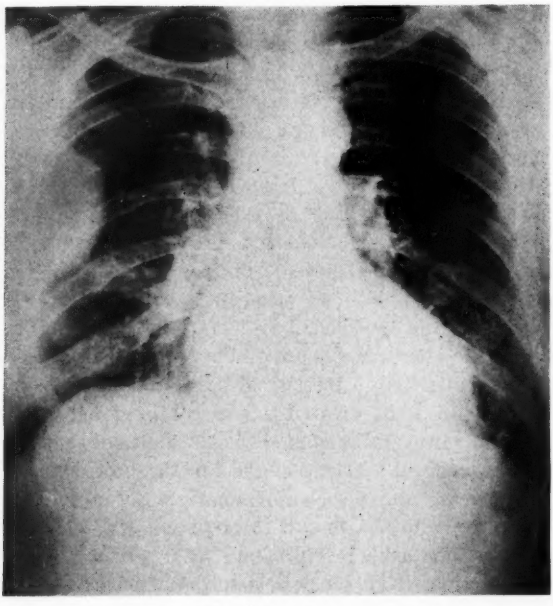


Fig. 1.—Preoperative roentgenogram of the chest in Case 1, showing tumor of the right chest wall with partial destruction of the sixth rib.

When the skin and subcutaneous tissue do not have to be removed, we have used tantalum mesh gauze in reconstructing the thoracic wall. Tantalum mesh gauze is more pliable than plate, and has been used successfully in the repair of a variety of hernias, ventral, indirect inguinal, direct inguinal, obturator, and recurrent inguinal.[6, 12] More conservative treatment consisting of a corset with a pad or obturator over the deep defect can be used, but it is not curative.[10, 11] One prefers not to bury a foreign substance when repairing a thoracic hernia, but if the defect is large this method may offer a satisfactory solution. In the two cases presented herein, tantalum mesh gauze (50 by 50 mesh of .003 inch tantalum wire) was used to reconstruct large thoracic defects.

CASE REPORTS

CASE 1.—St. Luke's Hospital, No. A 160-202. A 51-year-old white man was admitted on Dec. 18, 1948, with intermittent pain in the right infrascapular region, usually brought on by coughing. He had a chest roentgenogram taken seven months before admission which was negative. When the pain persisted cholecystogram followed by a roentgenographic examination of the colon were performed, and the only abnormal finding was diverticula of the colon. There was no history of hemoptysis, productive cough, or weight loss. One week before admission, or approximately seven months after the first roentgenogram, a second roentgenogram of the chest revealed a tumor of the lateral chest wall extending from the level of the second to the fourth anterior interspaces. The tumor had apparently destroyed the sixth rib in the region of the axilla. The main density projected medially for approximately 5 centimeters (Fig. 1).

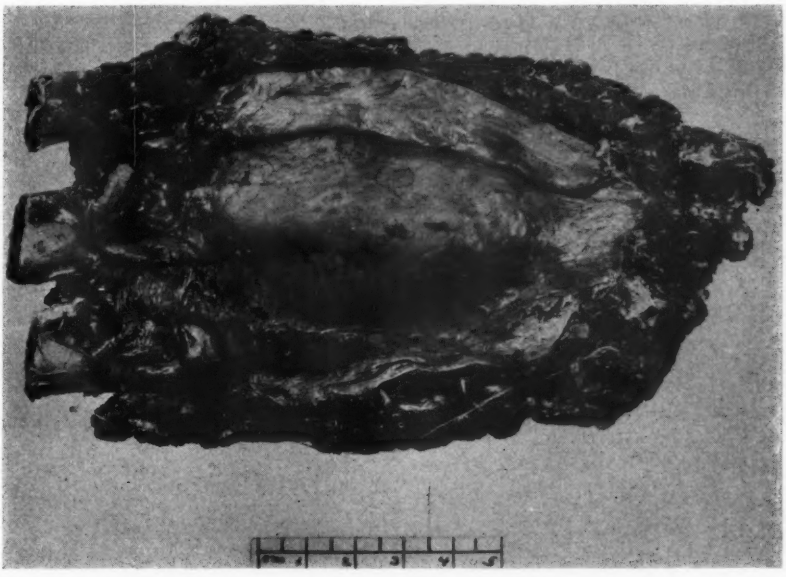


Fig. 2.—Tissue including the tumor, removed from the right chest wall in Case 1. Photograph of the pleural surface.

On physical examination the patient was a well-developed man who did not appear acutely or chronically ill. Temperature was 98.8° F., blood pressure 126/74. Eyes, ears, nose, and throat were normal. Lungs were clear to percussion and auscultation, and no masses could be felt in the thoracic wall. The liver was at the costal margin. No abdominal masses were felt. Neurologic examination gave essentially normal findings.

Laboratory examination showed a hemoglobin of 60 per cent (8.8 Gm.), red blood cells 3,600,000, white blood cells 5,300, polymorphonuclear leucocytes 60 per cent, lymphocytes 36 per cent, monocytes 4 per cent. There was moderate hypochromia and slight anisocytosis. Urinalysis showed an acid reaction, a specific gravity of 1.020, a 1 plus albumin, and was negative for Bence-Jones protein. On microscopic examination an occasional white blood cell was seen, and there were numerous hyaline casts. Urea nitrogen was 11.8 mg. per cent. Serum proteins were 6.8 Gm. per cent, albumin 4.0 Gm. (60 per cent), and globulin 2.8 Gm.

(40 per cent). Roentgenograms of the skull showed several areas of rarefaction, which were more suggestive of venous sinuses than bone destruction. Sternal marrow biopsy was not performed. Preoperative diagnosis was primary osteolytic tumor of the right thoracic wall.

Two days after admission operation was performed under endotracheal gas-oxygen, and cyclopropane anesthesia. A transverse incision approximately 16 cm. in length was made from the anterior axillary line, across the inferior tip of the scapula overlying the sixth rib, and through the latissimus dorsi and serratus anterior muscles exposing the tumor. A biopsy of the fusiform swelling of the sixth rib in the posterior axillary line was performed, and a frozen section of the specimen removed was reported to be a sarcoma of undetermined type. A block excision of the right fifth, sixth, and seventh ribs with intercostal muscles and pleura was then performed from the anterior axillary line to a point 14 cm. posterior to it. Drill holes were placed through the rib ends and through the fourth rib above and the eighth rib below. A piece of tantalum mesh gauze with the edges doubled under was placed in the defect and secured with tantalum wire inserted through the drill holes and through the doubled edge of the gauze. The muscles were approximated with No. 00 interrupted chromic catgut sutures placed in the fascia. The subcutaneous tissue was closed with interrupted No. 00 plain catgut, and the skin was closed with interrupted No. C silk. During the operation the patient received a transfusion of 500 c.c. of citrated whole blood.

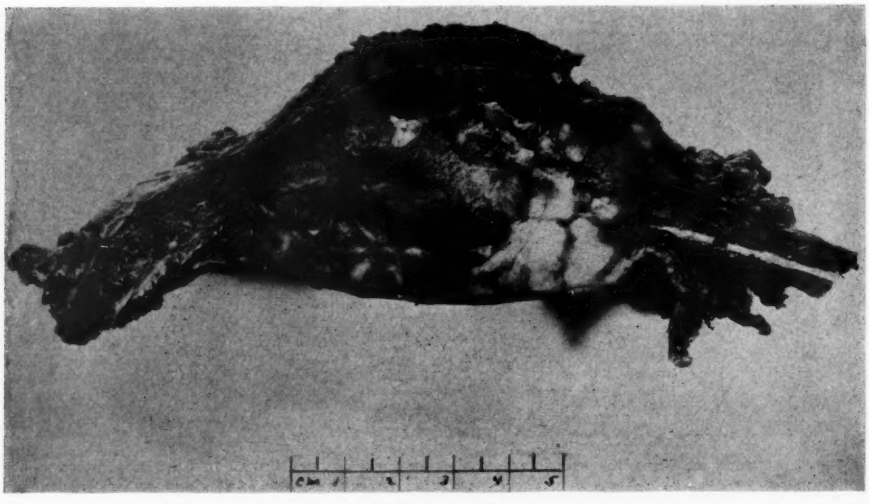


Fig. 3.—Section through the sixth rib in Case 1, showing the tumor.

Gross pathologic examination showed a specimen consisting of the right fifth, sixth, and seventh ribs, 12 cm. to 14 cm. in length (Fig. 2). The inner surface was covered with intact, smooth, shiny pleura, the outer surface consisted mainly of muscle. The cut ends of the ribs showed normal appearing red marrow. The central rib had a fusiform swelling 8 cm. long and approximately 5 cm. in maximum diameter. The sixth rib was split longitudinally, and showed the central part of the rib to be destroyed and replaced by a soft, hemorrhagic, fleshy tumor with approximately 2.5 cm. of normal appearing rib at each end (Fig. 3). Microscopic examination showed cells typical of a plasma cell myeloma with numerous mitotic figures.

Postoperatively the patient received 100,000 units of penicillin intramuscularly every four hours for the first ten days. His temperature was 103.0° F. on his first postoperative day, but gradually returned to normal. He received a second transfusion of 500 c.c. of

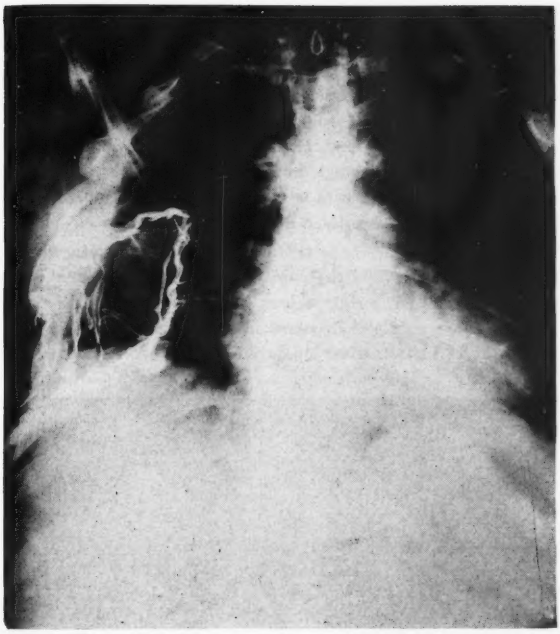


Fig. 4.—Roentgenogram of Case 1 taken eight months postoperatively, showing the tantalum mesh gauze in position in the operative defect of the right chest wall.

Fig. 5.—Lateral view of Case 1 taken at the same time as Fig. 4.

citrated whole blood on his third postoperative day; on the same day he developed auricular fibrillation, and signs of fluid in the right thorax. The auricular fibrillation subsided spontaneously, and right thoracentesis yielded 300 c.c. of bloody fluid. A right thoracentesis was done again on the fifth postoperative day, and 275 c.c. of bloody fluid were removed; 80 c.c. and 50 c.c. of serous fluid were aspirated from the wound on the fifteenth and seventeenth postoperative days. No further thoracentesis or aspiration was required. He was discharged on his twenty-first postoperative day without sedatives or analygesics.

The patient has been given urethane treatment by Dr. N. L. Higinbotham of Memorial Hospital, New York City; and at this time, one year after operation, there is no suggestion of other bone lesions. The patient's right thorax is comfortable, and there is no lung hernia. Upon deep inspiration there is slight decrease in expansion on the right side. Follow-up chest roentgenograms, eight months after operation, are shown in Figs. 4 and 5.

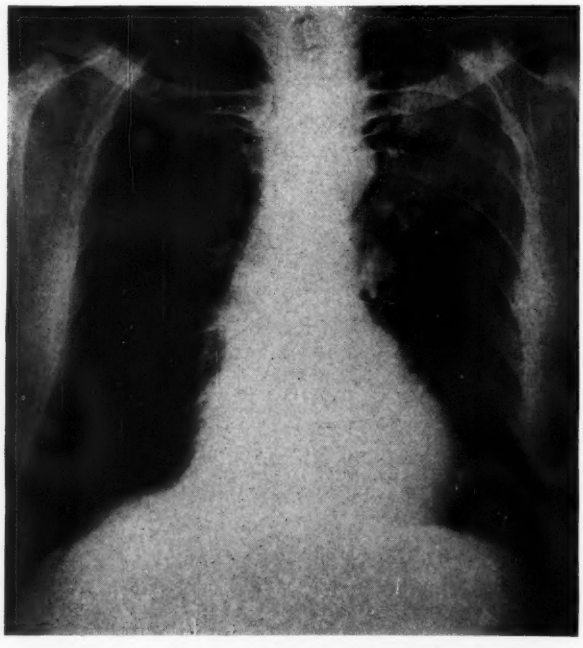


Fig. 6.—Anterior-posterior view in Case 2 showing a rounded density in the left upper lung field. Localized partial destruction of the posterior fifth rib can be seen.

CASE 2.—St. Luke's Hospital, No. 178-019. A 50-year-old man was admitted on Feb. 1, 1950, with precordial pain of five days' duration, which began while bending over. He had two coronary occlusions in 1945 and a third in 1947, for which he had been admitted to another hospital. After the onset of pain, a physical examination and an electrocardiogram were done at the hospital where he had previously been treated for coronary artery occlusions. No changes were noted, and the patient was sent home. The pain became more and more severe, and began to radiate down the left arm. Coughing and deep breathing were painful, and there was expectoration of thick yellow sputum.

Moderate dyspnea and orthopnea had been present since 1945, but there was no history of ankle edema, weight loss, chills, fever, hemoptysis, or night sweats.

On examination the patient appeared older than his stated age. Temperature was 98.4° F., blood pressure 122/74, pulse 80, and respirations 22 per minute. Eyes, ears, nose, and throat were normal. The chest showed an increased anterior-posterior diameter and fair expansion, and was clear to percussion and auscultation. There was deep tenderness elicited by percussion in an area 3 cm. by 3 cm. just to the left of the left nipple. The heart sounds were of fair quality and regular, without murmurs or thrills. On examining the abdomen, the liver descended 2 cm. below the costal margin on deep inspiration and was quite tender. No abdominal masses were felt. Rectal examination was negative. The prostate gland was of normal size and consistency. Proctoscopy to eight inches was negative except for small internal hemorrhoids.

Laboratory examination showed a normal red cell and white blood cell count, and urinalysis. Blood Mazzini was negative, blood urea nitrogen 12.1 mg. per cent, blood sugar 79 mg. per cent, serum phosphorous 2.8 mg. per cent, serum alkaline phosphatase 4.1 Bodansky units, serum acid phosphatase 3.3 Gutman units, erythrocyte sedimentation rate 26 mm./hr. The sputum was negative for acid fast bacilli. The stools were negative for occult blood.

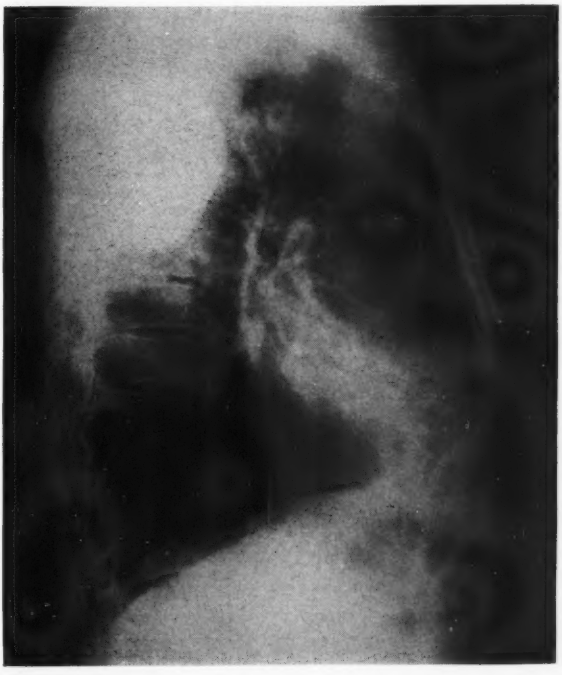


Fig. 7.—Lateral view in Case 2 showing the density situated in the upper posterior thorax.

An x-ray examination of the chest showed a tumor, 10 cm. in diameter, situated in the posterior portion of the left upper lung field. There were increased vascular markings, obliteration of the left costophrenic sinus, and slight cardiac enlargement. Repeated roentgenograms showed progressive increase in the size of the lesion, and localized destruction of the fifth rib (Figs. 6 and 7). Bronchoscopy was negative, and bronchial washings examined by the Papanicolaou technique were negative for malignant cells. Skeletal x-ray survey

failed to reveal any other bone lesions. Gastrointestinal and urological investigations showed no abnormalities. Electrocardiograms gave evidence of an old posterior coronary occlusion.

Six weeks after admission a left thoracotomy was performed under endotracheal nitrous, cyclopropane, and ether anesthesia. The thorax was entered through the sixth interspace, and a tumor approximately 10 cm. by 10 cm. by 4 cm. was seen attached to the fourth, fifth, and sixth ribs just to the left of the transverse processes. It was also attached to the periphery of the left upper lobe. A block excision of approximately 15 cm. square of the chest wall was performed consisting of fourth, fifth, and sixth ribs, intercostal muscles, parietal pleura, tumor, and peripheral portion of left upper lobe. A 15 square centimeter piece of tantalum mesh gauze was then made with the edges doubled under, to fit the defect. Drill holes were placed in the adjacent ribs, and interrupted tantalum wire was used to hold the mesh in position. A Foley bag catheter was placed through a stab wound in the eighth interspace and attached to underwater drainage. The outer structures of the chest wall were closed as in the previous case. During the operation the patient received a transfusion of 500 c.c. of citrated whole blood.

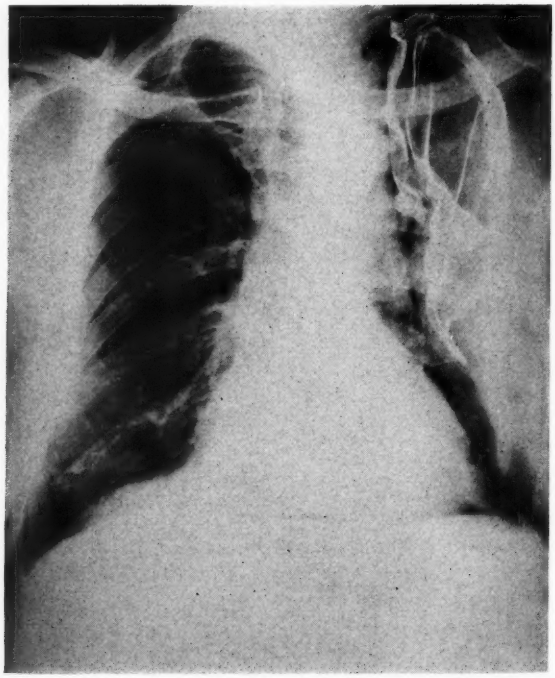


Fig. 8.—Anterior-posterior view in Case 2, one month postoperatively.

On gross pathologic examination the specimen consisted of a tumor mass 7.5 cm. by 8 cm. by 4 cm., attached to the inner surface of three ribs, each of which was 13 cm. in length. The inner surface of the tumor was covered with smooth, shiny serosa except for a ragged section of lung tissue. On microscopic examination there were sheets and cords of tumor cells tending to form small glands. The cells varied in size and shape, and in one section were invading bone marrow. Diagnosis was metastatic adenocarcinoma involving the chest wall. There was nothing in the histology to suggest the origin of the tumor.

Postoperatively, the patient received 200,000 units of penicillin intramuscularly every six hours for the first eight postoperative days. The temperature rose to 102.2° F. on the first postoperative day, and fell to normal on the second postoperative day, where it remained. The catheter was removed from the thorax on the seventh postoperative day, and no aspirations of the thorax were required. There was pain in the incision following operation, but it gradually decreased, and the patient was comfortable at the time of discharge on the twenty-first postoperative day.

On physical examination one month after operation the incision was well healed, with only slight tenderness in the region of the repair, and there was no evidence of lung hernia. There was slight decreased expansion on the left side when taking a deep breath. Check-up roentgenograms showed the tantalum mesh gauze to be in position in the defect; most of the tantalum wire sutures, however, were broken (Fig. 8).

DISCUSSION

In the two cases presented, tantalum mesh gauze has been well tolerated by the tissues during the relatively short period of observation. We believe it is superior to tantalum plate, when the defect occurs in the region of the ribs, where there is motion and shearing stresses and strains. The mesh can be fashioned to fit any type of defect, and is readily fixed in position with tantalum wire to bone or soft tissue. The plate would probably be more useful for repairing defects of the sternum, or for stabilizing the upper anterior thorax after removal of the manubrium and sternal ends of the clavicles. The gauze has remained in situ, and the patients have been fairly comfortable since the time of discharge. The tenderness displayed in the region of the repair of the second patient may be due to the irritation of the broken wires.

The tumor in the first case was to all appearances a solitary plasma cell myeloma. In such cases, destruction or removal of this type tumor appears justified.[3, 7] In the second case, the tumor was an adenocarcinoma of as yet undetermined origin. Operation has afforded the patient relief from pain, but there is some tenderness in the region of the repair.

SUMMARY

1. Methods of reconstruction of the thoracic wall have been reviewed.

2. A method of repair of the thoracic wall is presented, wherein tantalum mesh gauze has been used to fill the defect of the bony thoracic wall. Two cases with this type of reconstruction are presented.

REFERENCES

1. Beardsley, J. M.: The Use of Tantalum Plate When Reconstructing Large Areas of the Chest Wall, J. THORACIC SURGERY **19**: 444-455, 1950.
2. Campbell, D. A.: Reconstruction of the Anterior Thoracic Wall, J. THORACIC SURGERY **19**: 456-461, 1950.
3. Christopherson, W. M., and Miller, A. J.: A Re-evaluation of Solitary Plasma Cell Myeloma of Bone, Cancer **3**: 240-252, 1950.
4. Goodman, H. I.: Hernia of the Lung, J. THORACIC SURGERY **2**: 368-379, 1933.
5. Graham, E. A.: Hernia of the Lung and Adenoma of the Thyroid, S. Clin. North America **2**: 1493-1500, 1922.
6. Jefferson, N. C., and Dailey, U. G.: Incisional Hernia Repaired with Tantalum Gauze, Am. J. Surg. **75**: 575-579, 1948.
7. Kinsella, T. J., White, S. M., and Koucky, R. W.: Two Unusual Tumors of the Sternum, J. THORACIC SURGERY **16**: 640-667, 1947.

8. Maurer, E., and Blades, B.: Hernia of the Lung, J. THORACIC SURGERY **15**: 77-98, 1946.
9. Montgomery, J. G., and Lutz, H.: Hernia of the Lung, Ann. Surg. **82**: 220-231, 1925.
10. Olin, H. A.: Hernia of the Lung, Radiology **20**: 253-266, 1933.
11. Pain, A. B.: Hernia of the Lung, Brit. M. J. **1**: 59, 1934.
12. Throckmorton, T. D.: Tantalum Gauze in the Repair of Hernias Complicated by Tissue Deficiency, Surgery **23**: 32-46, 1948.
13. Tuffier: De la Resection du Sommet du Poumon. Semaine Med. **11**: 202-203, 1891.
14. Volger, M.: Beitrag zur Kenntniss der Traumatischen Lungenhernien, Monatschr. f. Unfallheilk. **5**: 169-176, 1898.
15. Vulpius, O.: Ein Versuch zur heilung der lungenhernie, Berl. Klin. Wchnschr. **37**: 1152-1154, 1900.
16. Watson, W. L., and James, A. G.: Fascia Lata Grafts for Chest Wall Defects, J. THORACIC SURGERY **16**: 399-406, 1947.
17. Winkel, A. H.: Hernia of the Lung, J. THORACIC SURG. **4**: 627-634, 1935.

OBSERVATIONS ON DIVISION OF ADHESIONS IN OPAQUE LOBES

ALFRED J. COELLO, M.D. (BARCELONA)
BARROW-IN-FURNESS, ENGLAND

IN THESE days, when the treatment of pulmonary tuberculosis seems to oscillate between such extremes as streptomycin at one end and lung resection at the other, both being recent acquisitions in the treatment of this disease, to talk of "black-out" lobes in artificial pneumothorax in relation to healing may sound rather out of place to some. This subject has been investigated and discussed at great length by several authors years ago, and although opinions are still divided about its beneficial or dangerous effects, I feel that the last word has not yet been said, and further contributions to its clarification should still be welcome.

From time to time reports have appeared in the Journals devoted to tuberculosis where, after having operated on a few hundred cases of artificial pneumothorax, the author feels obliged to tell us about his results with the Jacobaeus operation.

These results are usually given with a great profusion of figures, charts, and tables. The conclusions almost invariably contain figures on sputum conversion, cavity closures, pleural complications, cures, improvements, and so on, thus putting down into arithmetic something so variable and poliomorphic in its very nature as is the behavior of tuberculous lesions in different individuals.

From the review of such papers one principle seems to stand out and dominate the whole field of this operation, namely the mechanical conception that a successful Jacobaeus operation is one in which all adhesions have been severed, wherever they are, whatever their type may be, regardless of their number. Fortunately, all the authors are agreed on the dangerous practice of leaving broad adhesions halfway cut, particularly if they are apical and close to the tuberculous lesions.

I often wonder how much scientific ground there is for the widespread belief that adhesions are the main source of pleural complications in the pneumothorax; also for the other accepted principle that a pneumothorax with adhesions cannot be a good pneumothorax. In pulmonary tuberculosis nothing can be easier than to prove anything, from the senseless contention that early hemoptysis can be a sign of good prognostic significance to the not so senseless theory that pleural thickening may encourage healing by starting a process of peripheral fibrogenesis.

Side by side with an ineffective pneumothorax free from adhesions it is quite easy to put another one, where, despite "inseparable" adhesions there

Received for publication Aug. 10, 1950.

exists selective collapse, and yet the result has been satisfactory. This is not only so in relation to sputum conversion, but also where closure of cavities is concerned. The nature of tuberculous lesions and individual resistance to the disease is such that the closure of cavities and resolution of infiltrative lesions does not always come about by such a simple maneuver as the cutting of a few bridges of pleural tissue. The importance of pleural adhesions in pneumothorax is not a quantitative factor, but rather one of quality. More important than the adhesion itself is its relation to the underlying lesion, its influence, unfavorable or even favorable toward the progression or regression of the diseased area. Everybody has witnessed the progression of a tuberculous lesion despite a good pneumothorax, and vice versa.

The tendency nowadays, however, is to submit more cases of pneumothorax for early thoracoscopy with a view to division of adhesions, even if none can be seen in the roentgenogram.

I feel that the importance of the presence of adhesions in pneumothorax has been rather overestimated, probably because it is a relief to our conscience to feel that should a complication appear in the course of refills, no blame can now be pinned on such an elementary precaution as is the severing of any offending adhesions that may be present. As if a pneumothorax with or without adhesions were not, in itself, a dangerous procedure! "Walking on the edge of a volcano" Robert Coope has called it.

Needless to say, the excellent results obtained in well-selected and skillfully managed cases, justifies the increasing use of this form of treatment, and this being so, we must be prepared, now and then, to meet such complications as pleural effusions, spontaneous pneumothoraces, etc.

Alexander and Deist estimated that only 14, or 25 per cent of all cases of pneumothorax are suitable for adhesiotomy. About 40 per cent of pneumothoraces are unsatisfactory on account of the presence of offending adhesions (Matson). From the results obtained by many authors, 60 per cent of these pneumothoraces can be converted into satisfactory ones by division of the adhesions, otherwise only 15 per cent of them may prove to be worth while continuing with.

As for complications, I think it is safe to put the incidence of pleural effusions, large and small, at 40 per cent of all cases submitted to adhesiotomy, 8 per cent of them turning empyematous soon, or later on after the operation if the treatment has been continued for longer than six months.

With regard to these complications I feel it is only fair to say that they do not represent a regular event in the routine work of a chest surgeon. I feel that the highest incidence of empyemas following adhesion section in any given series represents the unpleasant tribute paid by the surgeon for his first hundred cases. The incidence of pleural complications decreases gradually proportionate to the skill and experience of the surgeon. I wonder how many of the 19 per cent of empyema cases of Matson, 14 per cent of Matill-Jennings, 8 per cent of

Goorwitch, and 13 per cent of P. W. Edwards did happen among the first hundred cases operated upon, and if they would get the same figures today with their broader and much increased knowledge of the technicalities of this operation and better selection of cases, etc.

On reviewing the work on the Jacobaeus operation, published by Jacobaeus himself, Alexander, Anderson, Matson, Brock, P. W. Edwards, Cutler, Marcus Pinner, Xalabarder, Laird, Aubrey-Jones, Goorwitch, Stemmerman, Weber, Herholtz, O'Shaughnessy, Newton, Chien, and others, I find that special emphasis has been placed on such items as sputum conversion and caivty closure, undoubtedly the main objectives of this operation. Next, these authors concentrate their investigation on operative and postoperative complications, technique employed, results according to the extension of the disease, etc., but no information can be found as to the radiologic and pathologic types of the disease, a point of considerable importance. Apart from Coryllos who left us an enthusiastic defense of the beneficial role played by atelectasis in pneumothorax and other papers dealing with this subject along polemical lines, no practical work can be found on a large series of such cases. It is not reasonable to be dogmatic either for or against lobar atelectasis in pneumothorax just because bad or good results have been obtained in a small group of cases. "Black-out" lobes may result in cavity closure and sputum conversion in some cases, and may also bring about a dangerous state of affairs for reasons not yet well established. This paper is an attempt to bring more light on the interpretation of this apparent paradox, and is based on the experience of over 300 cases of the Jacobaeus operation. A total of 57 cases of opaque lobes have been studied and compared. As a result it is felt that the beneficial effects of lobar atelectasis observed in one group of cases and the bad results obtained in another are not solely due to the classical division of tuberculous lesions into productive and exudative—other factors also play an important role. Cases of transient or temporary atelectasis observed during pneumothorax are not considered in this series.

Of the three main theories put forward for the explanation of "opaque lobes" in pneumothorax, namely, bronchial obstruction (Coryllos), pneumonitis (Pinner), and active contraction of the alveoli (Xalabarder), we feel that none can be accepted as a single causative factor. By Bronchography it has been shown that in a number of cases of opaque lobes lipiodol may not only fill the main bronchi and secondary branches, but also the most distal alveolar territories, and this is taken to be a clear proof that there can be lobar atelectasis without bronchial occlusion or exudative engorgement.

By thoracoscopy it is quite common to see small pink patches of aerated lung tissue amid large areas of airlessness—"breathing zones" of Xalabarder. Radiology and thoracoscopy have shown that there are two main types of opaque lobes in pneumothorax: the flabby, wrinkled, bluish-colored lobe, triangular in shape; and the tense, roundish, shiny, grayish-colored, densely opaque one. This distinction in color, consistency, and shape is paramount because the prognosis of the pneumothorax in one case or the other is vastly different.

As a rule, on doing a thoracoscopy with a view to adhesion section, the first movement of the surgeon is to find out whether there are any adhesions present, the type of these adhesions, where they are inserted, if they are operable or not, etc., and little or no attention is paid to the appearances of the collapsed lung. The observation that cavity closure in opaque lobes is not necessarily the consequence of complete adhesion section led me to follow closely the behavior of this type of pneumothorax ever since 1943. In my experience total, incomplete, or partial division of adhesions in roundish and solid opaque lobes with cavities within does not alter matters much. If incompletely freed the cavity persists in the middle of the homogeneous density, or even may "balloon." If freed completely it simply descends and gravitates over the remaining aerated lung by its heavier weight, giving quite often rise to atelectasis of the whole lung, a dangerous state of affairs and one which would call for hasty reexpansion measures such as withdrawal of air, frequent change of posture, even bronchoscopic suction, this last procedure of no avail in sudden reflex apneumatosis.

On the contrary, triangular-shaped opaque lobes give a great percentage of cavity closures even without adhesion section, provided that these adhesions are not inserted against mobile structures of the chest wall. I am not advocating the discontinuance of the practice of adhesiotomy in these cases. As many adhesions as possible should be severed in any case of pneumothorax, but inoperability or incomplete division is not always synonymous with failure. Alexander and Anderson found that 41 per cent of their cases had incomplete division of adhesions, yet in 28 per cent the result of the treatment was satisfactory, and in 16 per cent definitely improved. Goorwitch had 69 per cent of

TABLE I

TYPE OF OPAQUE LOBE	WITH DIVISION OF ADHESIONS						WITHOUT ADHESION SECTION		TOTAL	
	GOOD RESULTS			BAD RESULTS			GOOD	BAD	GOOD	BAD
	ALL ADHESIONS CUT	SOME ADHESIONS LEFT	MAIN ADHESION LEFT HALFWAY CUT	ALL ADHESIONS CUT	SOME ADHESIONS LEFT	MAIN ADHESION LEFT HALFWAY CUT				
Triangular "Opaque Lobe" (Either before or after operation)	2	11	4	1	1	3	3	-	20	5
Round "Opaque Lobe" (Either before or after operation)	4	-	-	5	1	10	1	-	5	16
Whole Lung "Opaque"	1	-	1	1	2	2	2	2	4	7

incomplete divisions, yet 44 of 102 cases of incomplete adhesiotomy showed satisfactory relaxation of the diseased lung. Aubrey-Jones had 52 incomplete divisions of 401 cases, with 13 per cent of the former successful enough to justify their continuance. In Matson's series of 206 cases, 83 could not be completely divided, and 16 of these cases (7.7 per cent) did quite well. Unverricht had 26 per cent of good results in the incomplete division group, and Gravesen's figure for the same group was 33 per cent.

Unfortunately, for the support of my thesis, none of these authors specify the type of lesions present in those percentages of good results following incomplete adhesiotomy. Also, the term "incomplete" may mean half-way-cut adhesions or partial division only (some adhesions being left undivided).

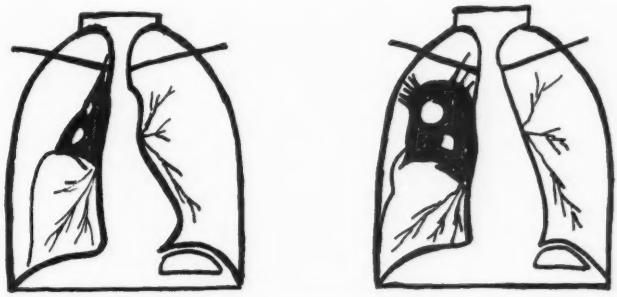


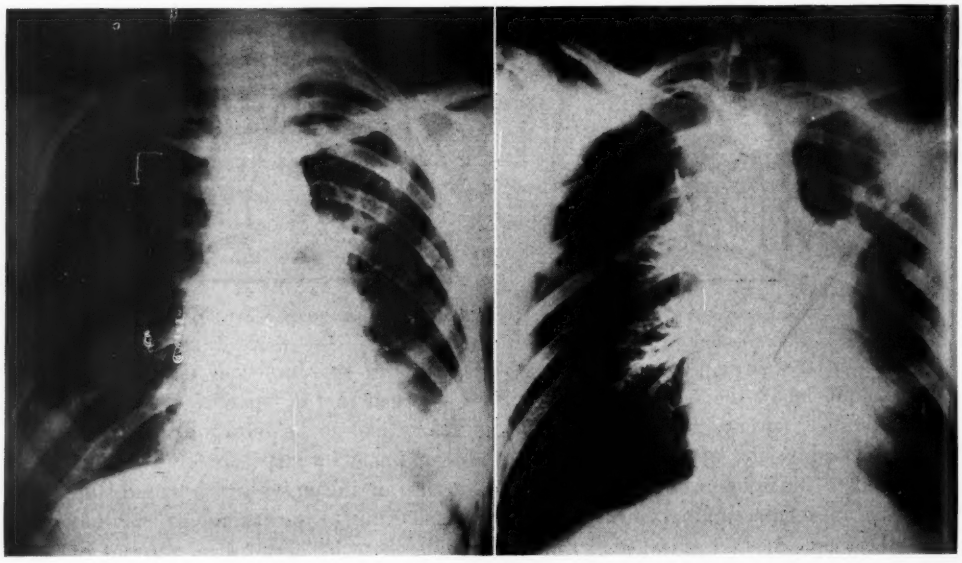
Fig. 1.—Triangular shaped "opaque lobe" (beneficial). Roundish "opaque lobe" (dangerous).

In the series presented here on the results of the Jacobaeus operation in opaque lobes, the best results have been obtained in the "partial division of adhesion" group, where one or two adhesions had to be left undivided and attached to the upper mediastinum or to an immobile structure of the chest wall. This apical attachment appears to act as an anchorage which would stop the apex from falling downwards, also contributing to the triangular shape of the lobe. If this apical anchorage is considered to be harmful on account of its tensive action on the underlying lesions and there are *also* diaphragmatic adhesions, thus making this tension a longitudinal one, the rational thing to do next is to paralyze the corresponding hemidiaphragm, resorting even to a short period of pneumoperitoneum (see Table I), if necessary, before abandoning the pneumothorax.

Once established, this distinction between triangular and roundish opaque lobes, the former beneficial, the latter dangerous, it is essential that we should try to find out the reasons for their different behavior. Why is it that in one case the lobe would collapse almost immediately, after a few refills, giving the impression of being soft, wrinkled, with a tendency to gradual and progressive retraction, while in the other cases the opaque lobe remains always solid, tense, really opaque, maintaining its consistency and spheroidal shape with or without adhesion section. Also, why is it that in the first group cavities tend to close

readily, while in the second group they seldom do, if at all? The answer to these questions must surely lie in the underlying anatomopathology of the affected lobe prior to the pneumothorax (Fig. 1).

With this in mind I have reviewed and compared the films of 57 cases of opaque lobes, before and soon after induction of the pneumothorax. They fall into two main groups, one termed "preatelectatic stage" by Xalabarder or "spastic lung" by Tapia, in which the affected lobe appears decreased in size, the mediastinum displaced toward the diseased lung, and the corresponding hemidiaphragm raised. The lobe is not completely "cut off" from the pulmonary aeration as can be proved by bronchography (Figs. 2*A* and *B*). The pulmonary pattern has not entirely disappeared, and, although there may be



A. *B.*

Fig. 2.—*A*, case of beneficial "opaque lobe" resulting in cavity closure. Bronchography has failed to show blockage of the main divisional branches of the upper lobe. (Fig. 2*B*.)

triangular or fanlike areas of shadow radiating from the hilum (usually the posterolateral segment), the apical and pectoral segments may still remain aerated. It is quite possible that there may be a certain degree of bronchial dilatation, but this bronchiectasis is rather a "dry" one, uncomplicated, harmless. Not infrequently there is a system of two or three small cavities within the lobe. By bronchoscopy the opening of the upper lobe appears quite patent and healthy. Clinically there are no physical signs of bronchial stenosis whatever; there is little cough and little sputum, no systemic disturbance, and the general condition of the patient quite disproportionate to the extension of the

pulmonary lesions. The study of this group of lesions rather recalls some of the cases described under different terms by Ornstein and Ulmar, Davidson and Ellman.

It appears that histologically the dominant feature is the disappearance of the alveolar pattern and the reduction of the blood flow. There is marked interstitial fibrosis, hialinization and collagenous changes around the bronchi and

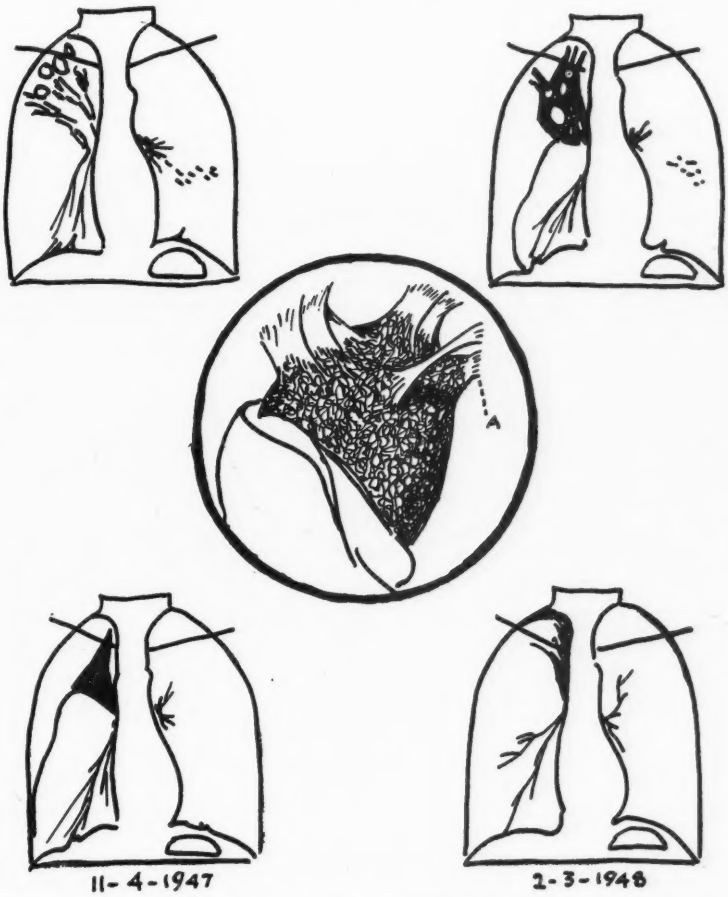


Fig. 3.—Case of beneficial "opaque lobe." Drawings reproduce radiological appearances before pneumothorax, after induction, thoracoscopic view (adhesion *A* left undivided) after adhesion section and final result.

blood vessels. This results in distorted and narrowed bronchioles where oxygenation of the blood must be negligible. The alveolar walls are thickened by the luxurious fibrogenesis and concomitant emphysema present. Reversibility of these changes is a very remote possibility, and is much hindered by the

fibrotic nature of the whole process. In a way this type of benign "lobitis" is to pulmonary tuberculosis what chronic interstitial pneumonitis is to other acute pneumonic and bronchopneumonic conditions of the lungs (Figs. 3, 4, and 5).

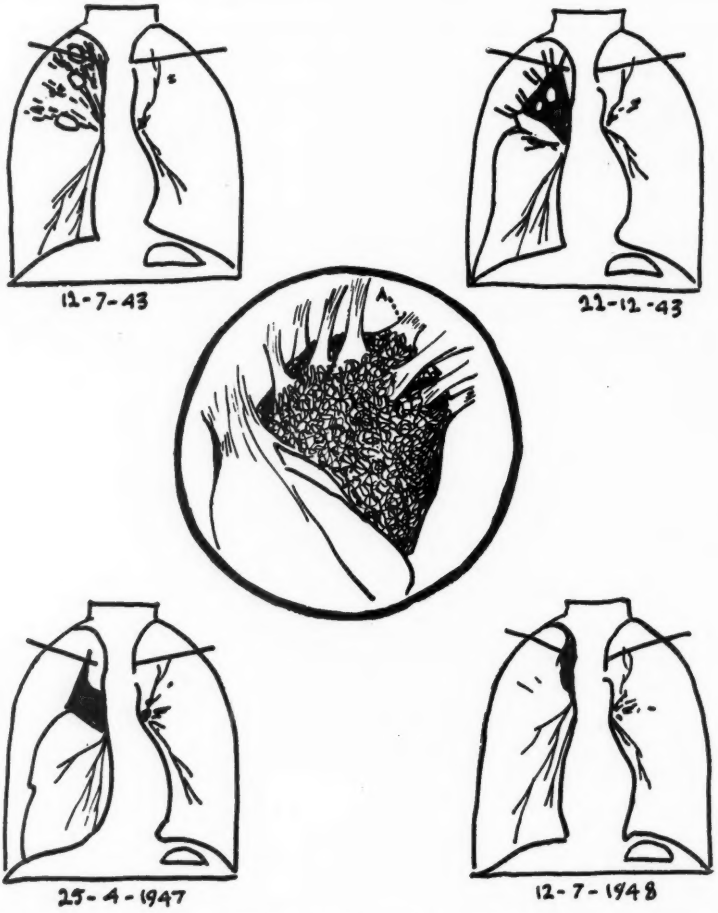


Fig. 4.—Case of beneficial "opaque lobe." Drawings reproduce appearances before induction of pneumothorax, soon after, thoracoscopic view (adhesion *A* left undivided), appearances following adhesion section and final result.

In the other group the roentgenogram prior to pneumothorax falls within two typical pictures: one of pneumonic consolidation, the other one similar to the benign group already described, with the difference that the lesions are nodular rather than reticular, striated, or linear, although in both cases there is a certain amount of lobar demarcation, the interlobar fissue moves much faster toward the clavicle in the benign group. Cough is a prominent feature

here, quite often unproductive, irritating. Auscultation reveals distinct sonorous rhonchi, quite musical in character, typical of bronchial narrowing. By bronchoscopy I have not been able to see such advanced cases of bronchial stenosis, occlusions, and obstructions as described by some authors. A constant finding, particularly in the left side, has been a marked degree of swelling and reddening of the mucosa amounting to submucus infiltration. The opening of

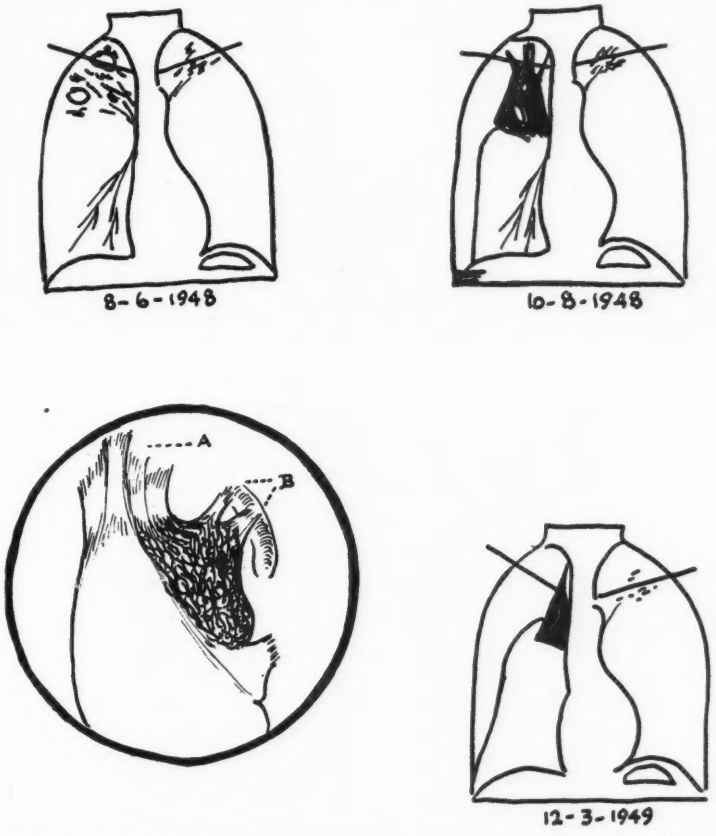
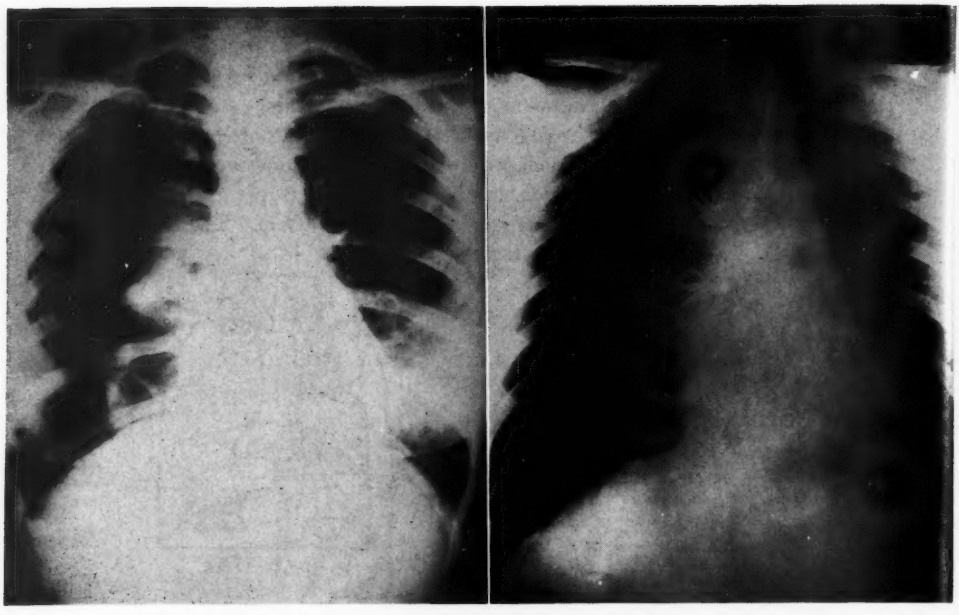


Fig. 5.—Case of beneficial "opaque lobe." Drawings reproduce appearances before pneumothorax, soon after induction, thoracoscopic view (adhesion *B* left undivided) and result following adhesion cutting.

the upper lobe bronchus is definitely narrower, sometimes deformed to a buttonhole shape. It has to be assumed that yonder these infiltrative changes are bound to end in a considerable degree of bronchial obstruction. Bronchography readily reveals the site of this blockage (Figs. 6*A*, *B*, *C*).

The pathologic changes consist mainly in alveolar, interalveolar, and bronchial engorgement of fibrinous and cellular exudates, together with vascular



A. *B.*

C.

Fig. 6.—*A*, case of dangerous "opaque lobe" where bronchography was done before adhesion section, this showing blockage of the main divisional branches closed to the pedicle of the lobe (Figs. 6 *B* and *C*).

dilatation. The muscular tonus and elastic properties of the lung tissue are irreparably damaged by gross toxic and necrotizing changes. Any hopes of "restitutio ad integrum" or tissue repair are here utopic unless bronchial drainage and elimination of debris assisted by good resistance and relaxation

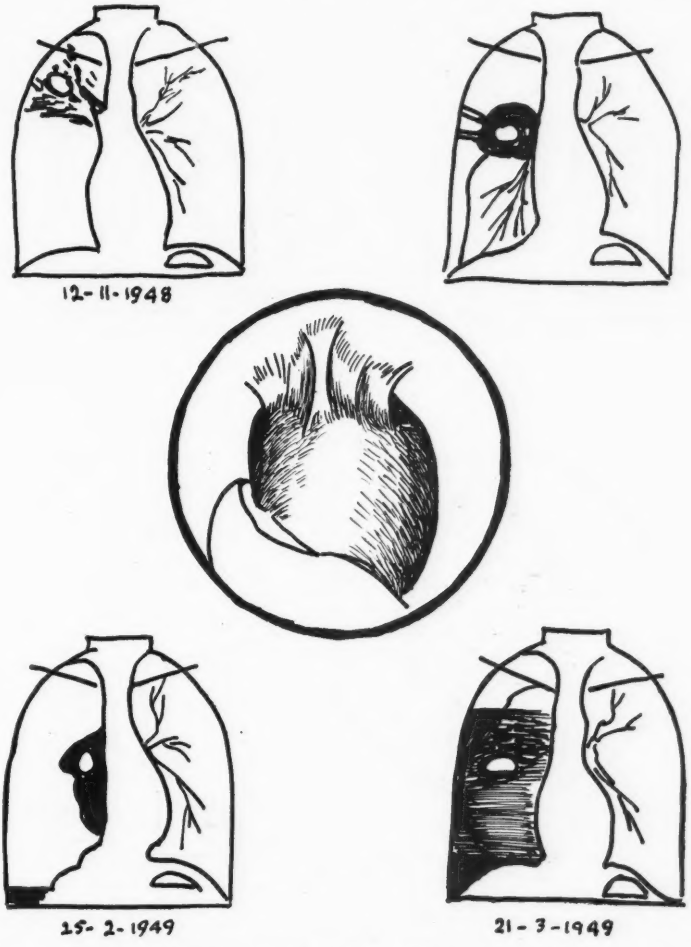


Fig. 7.—Case of dangerous "opaque lobe." Drawings reproducing appearances of roentgenograms before pneumothorax, after induction, thoracoscopic view (all adhesions were divided) and postoperative result.

therapy (pneumoperitoneum and phrenic paralysis) can cleanse the infected lobe and thus impede the extension of the disease to other parts of the lung, to start with. A pneumothorax, and further still a "free" pneumothorax, would naturally increase the bronchial obstruction with the disastrous result

of leaving highly toxic and necrotizing tissue entrapped and cut off from their natural draining channels (Figs. 7, 8, 9).

The tendency today is to submit these cases for pulmonary resection. Although by now a few hundred lobectomies have been performed for upper lobe tuberculosis, some of them for consolidated lobes, I have not been able to find

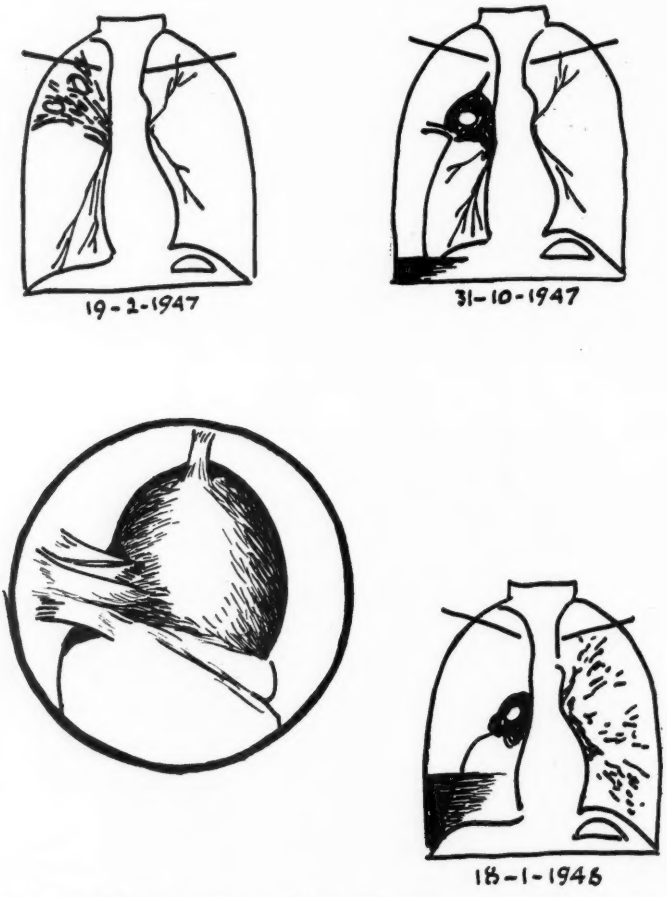


Fig. 8.—Case of dangerous "opaque lobe." Drawings reproduce radiological appearances before pneumothorax, after induction, thoracoscopic view (all adhesions were divided) and postoperative result.

enough cases to draw any worthy considerations as to the ultimate result of this form of treatment. Personally, I have followed up thirteen such cases treated by pneumoperitoneum preparatory to thoracoplasty, and the results have been, so far, highly satisfactory, definitely much superior to the results of similar cases treated by pneumothorax.

One point which is I think of considerable importance in the choice of treatment in each individual case is the general condition of the patient. A well-nourished patient, particularly of the female sex, with a triangular opaque lobe of the right upper lobe, has an almost certain guarantee of success.

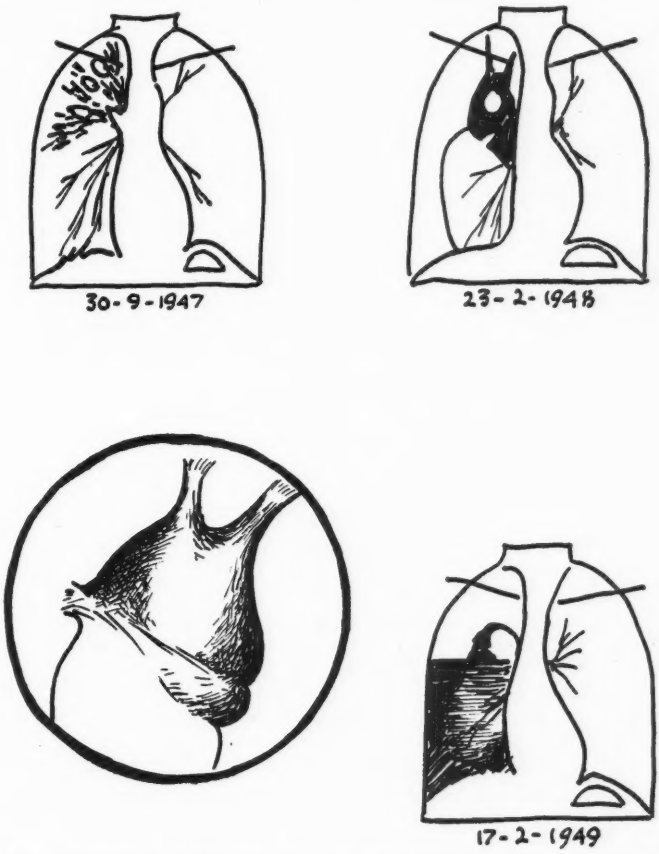


Fig. 9.—Case of "opaque lobe," dangerous type. Drawings from roentgenograms before pneumothorax, after induction, thoracoscopic view (all adhesions were divided) and post-operative result.

SUMMARY

Opaque or "black-out" lobes in artificial pneumothorax fall within two main groups: one in which the lobe appears much decreased in size, soft, wrinkled, dark blue, light in weight, triangular (radiologically); the other where the lobe appears tense, roundish, heavy (due to consolidation) shiny, and grayish. In the first group adhesion section should consist mainly in freeing the lung from the surrounding mobile structures without aiming at complete division. To leave the opaque lobe suspended from the upper mediastinum is

quite compatible with a satisfactory result, resorting, in case of concomitant diaphragmatic adhesions, to phrenic nerve paralysis if there is resulting longitudinal tension. As soon as cavity closure has been attained, the rest of the lung should be allowed to reexpand gradually by means of decreasing refills until the shrunken lobe appears cornered against the upper mediastinum giving the radiologic appearance of a collapse of the pectoral branch of the upper lobe. In these cases atelectasis can be highly beneficial, and the ultimate result comparable to selective thoracoplasty.

On the contrary, in the second group artificial pneumothorax is often very dangerous. Adhesion section seldom improves matters, and it would be safer to abandon it soon, resorting instead to a period of pneumoperitoneum and diaphragmatic paralysis preparatory to collapse or excision therapy.

These observations have been made prior to the extensive use now being made of streptomycin, P.A.S., and TRI-OM (S.32), the action of which in these types of disease seem to have had very little effect, so far, to alter substantially the results obtained prior to their use.

A table is presented with the results of 57 cases of adhesion section of opaque lobes together with considerations on their radiological, thoracoscopic, bronchographic and pathologic appearances (Table I).

REFERENCES

Adams, W. E., and Singer, J. J.: The Clinical Improvement of Pulmonary Tuberculosis by Massive Atelectasis, Am. Rev. Tubere. **31**: 373-385, 1935.

Aubrey-Jones, H.: Indications for Intrapleural Pneumonolysis, Am. Rev. Tubere. **52**: 355, 1945.

Barnet, P. Stivelman: The Role of Atelectasis in Pulmonary Tuberculosis, Am. Rev. Tubere. **30**: 60-71, 1934.

Coello, A. J.: La atelectasia pulmonar en el tratamiento de la tuberculosis, Med. clin. **13**: 71-82, 1949.

Coello, A. J., and Nagley, M.: Observations on Atelectasis, Tubercle **29**: 231, 1948.

Coryllos, P. N.: The Importance of Atelectasis in Pulmonary Tuberculosis, Am. Rev. Tubere. **28**: 1-26, 1933.

Edwards, P., et al.: Late Results of Closed Intrapleural Pneumolysis, Brit. Med. Jour. **11**: 270, 1944.

Goorwitch, J.: Complications of Closed Intrapleural Pneumonolysis, Am. Rev. Tubere. **48**: 205, 1943.

Holcomb, F. W., and Weber, G. W.: Atelectasis and the Disappearance of Cavities, Am. Rev. Tubere. **30**: 299-306, 1934.

Matson, R. C.: Surgical Diseases of the Chest, By E. A. Graham, J. J. Singer and H. C. Ballon.

Newton, H. F.: Intrapleural Pneumonolysis, Am. Rev. Tubere. **41**: 22, 1940.

Tannenberg, T., and Pinner, M.: J. THORACIC SURG. **11**: 571-616, 1942.

Xalabarder, C.: Atelectasia. Publicaciones del Instituto Antituberculoso, Barcelona, vols. III, V, VI, 1939, 1943, 1945.

ANGIOCARDIOGRAPHIC FINDINGS IN THORACOPLASTY, ARTIFICIAL PNEUMOPERITONEUM, AND PHRENICLASIA

HERBERT I. MCCOY, M.D., ISRAEL STEINBERG, M.D., AND CHARLES T. DOTTER, M.D., NEW YORK, N. Y.

IN A recent study the angiocardiographic findings in patients with artificial pneumothorax were presented.[1] These consisted of a diminution in vascularity which was directly proportional to the degree of collapse. There was crowding, distortion, and displacement of pulmonary vessels, and delay in blood flow in the collapsed lung. Varying degrees of shift of the heart, great blood vessels, and mediastinum were noted. The purpose of this report is to illustrate the angiocardiographic findings in other forms of collapse therapy commonly employed in the treatment of pulmonary tuberculosis, namely thoracoplasty, artificial pneumoperitoneum, and phreniclasia. In the past, visualization studies of the pulmonary circulation following thoracoplasty and phrenic nerve crush have been done by postmortem injection of opaque substances.[2] Whether or not autopsy findings accurately represent the changes which occur in the pulmonary circulation of the living individual has been questioned.[3] Such autopsy studies simply show the blood content of the lungs at death. Angiocardiography, on the other hand, affords an excellent method of roentgenographic visualization of the pulmonary artery and its branches in the living individual. Knowledge of the status of the pulmonary circulation in collapse therapy is important, since the circulation bears a direct relationship to the efficiency of respiration. Furthermore, changes in the circulation within the collapsed lung may play a dominant role in the healing of pulmonary tuberculosis.[4]

METHOD

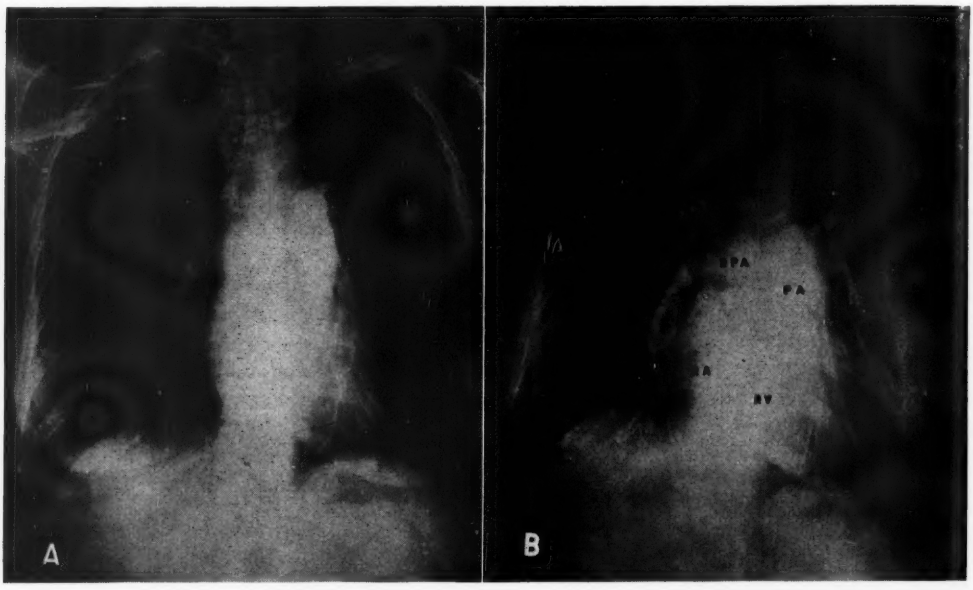
For the most part, angiocardiography was conducted as originally described using a standard stereo-cassette changer permitting two films per injection.[5] Contrast substance rapidly injected into an antecubital vein passes into the right heart chambers, then to the pulmonary arteries, returning via the pulmonary veins into the left heart chambers, finally making the aorta visible. Roentgenograms were taken at appropriate intervals to visualize best the heart, great vessels, and lesser circulation. In some cases, the Fairchild automatic roll-film magazine[6] was used, enabling roentgen exposures to be made at half-second intervals during the period of opacification. Either Neo-Iopax 75 per cent[7] or Diodrast 70 per cent was used as contrast substance. Neither substance causes iodism or activation of tuberculosis, since the iodine is so bound in an organic molecule as to be unavailable to the body.[8]

From the Departments of Medicine and Radiology of the New York Hospital-Cornell Medical Center.

This investigation was aided by grants from The New York Heart Association and The Schering Corporation.

Received for publication Aug. 23, 1950.

Seventeen tuberculous patients were studied at varying intervals before, during, and after collapse therapy. The types of collapse employed were thoracoplasty, artificial pneumoperitoneum, phrenic nerve crush, and a combination of the latter two. Interpretation of pulmonary vascular changes was made from comparison of the opacified pulmonary circulation of the collapsed lung with that of the noncollapsed lung, as well as from comparison of serial contrast studies in the same individual. These changes included variations in caliber, degree, and rate of filling, position, and configuration of the pulmonary arterial tree.



A. *B.*

Fig. 1.—(M.M. No. 182) Far advanced fibrocavernous tuberculosis of the left upper lobe in a 35-year-old woman, treated with thoracoplasty. *A*. Angiocardiogram shows the characteristic diminished vascularity of the left upper lobe. *B*. Angiocardiogram after an effective three stage thoracoplasty. Left lung volume markedly diminished. Left upper lobe vasculature diminished and pulmonary artery at left hilum appears more compact. RA=right atrium; RV = right ventricle; PA = pulmonary artery; RPA = right pulmonary artery.

FINDINGS

A definite decrease in vascularity of local areas of the lung involved by tuberculosis has been demonstrated both by angiocardiography[8, 9] and by injection studies in autopsy material.[2]

A. *Thoracoplasty.*—Following thoracoplasty there is, in addition to the avascularity at the site of the tuberculous process, a marked decrease in the vascularity of the collapsed lung roughly proportional to the degree of collapse (Figs. 1*B*, 2*C*, 3*C*). This is evidenced by crowding together, diminution in caliber, and nonfilling of pulmonary vessels. A shift of the heart and great vessels toward the noncollapsed side may occur (Figs. 1*B*, 2*C*, 3*C*). In extensive

unilateral fibrosis due to tuberculosis there is retraction of the heart, mediastinum, trachea, and great vessels into the affected side. All these structures form a homogeneous shadow which on conventional roentgenograms cannot be differentiated. This may be called "fibrothorax."[10] When fibrothorax exists prior to thoracoplasty (Figs. 3*A*, 3*B*), angiocardiography may serve to delineate the great vessels and cardiac chambers usually showing rotation and displacement of these structures. Marked distortion of the heart and great vessels in this

A.

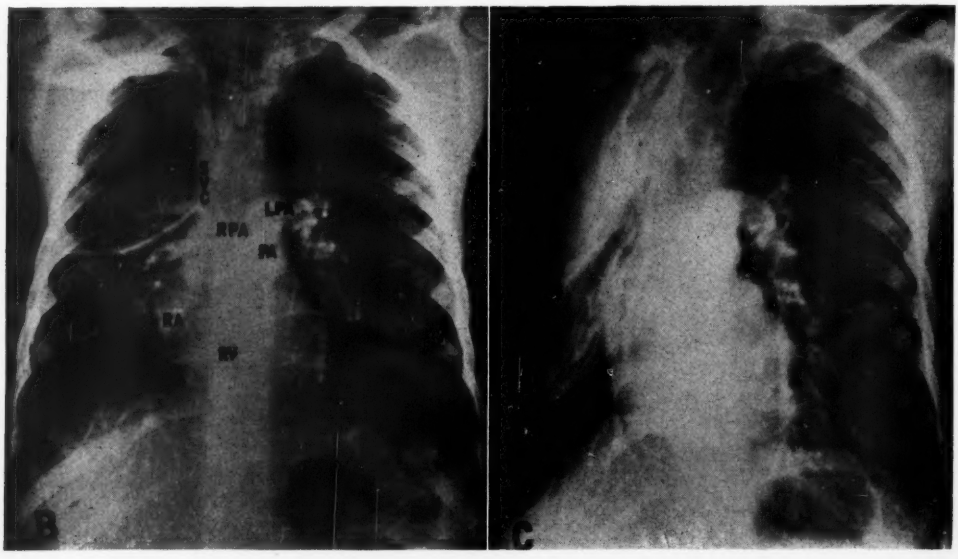
Fig. 2.—(W.S. No. 243) Far-advanced fibrocaseous tuberculosis of the right upper lobe in a 15-year-old Puerto Rican treated with thoracoplasty. *A.* Conventional roentgenogram showing a 2 by 2 cm. cavity behind the first right anterior rib with bronchiogenic spread to the mid-lung field.

condition may be corrected to some measure by thoracoplasty. Figure 3*C* illustrates a return of these structures toward a more normal anatomic relationship following operation. Postoperatively, the pulmonary vessels on the noncollapsed side can be seen to be less widely separated, suggesting partial correction of the overdistension of this lung.

B. *Artificial Pneumoperitoneum.*—Visualization studies in tuberculous patients receiving artificial pneumoperitoneum revealed upward displacement of the heart and great vessels, often with cardiac rotation (Figs. 4, 5, 6). In some

instances, with the patient in the erect position, the elevated right hemidiaphragm caused medial displacement of the lateral wall of the right atrium (Figs. 5, 6). The displacement appeared to be less when the elevation of the diaphragm was less as, for example, in the reclining position.

Following pneumoperitoneum the peripheral pulmonary vessels were brought closer together, and diminution and delay in opacification occurred variably. The greater the elevation of the diaphragm, the greater was the upward displacement and crowding of the pulmonary vessels. When a phrenic nerve crush was added to the pneumoperitoneum, resulting in an even greater



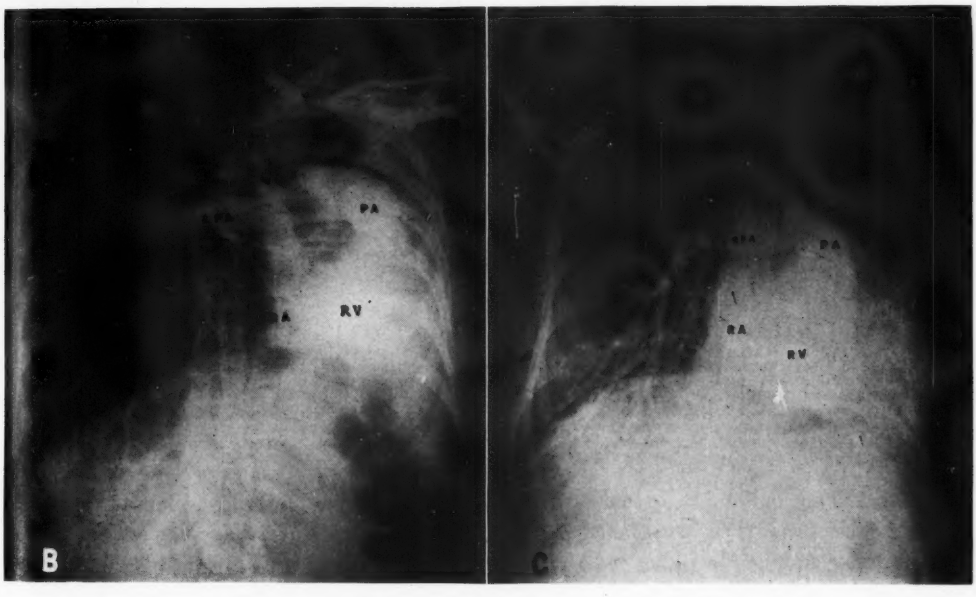
B. *C.*

Fig. 2.—*B.* Angiocardiogram five months later after preliminary collapse by an ineffective extrapleural pneumothorax. Only origin of right ascending pulmonary artery is opacified while right upper lobe is avascular. *C.* Angiocardiogram six months later after an effective three stage thoracoplasty. Right ascending pulmonary artery visualized only at orgin while right upper lobe is still avascular. The right pulmonary artery and its descending branch is compressed at the hilum.

rise of the hemidiaphragm, the vascular changes described above were accentuated on the homolateral side. Figure 6*A* and *B* not only illustrates medial displacement of the lateral wall of the right atrium, but also a narrowing of the lumen of the superior vena cava as it enters the heart. Distal to the narrowed portion there is some dilatation.

C. *Phrenic Nerve Crush.*—Along with the elevation of the diaphragm and local avascularity associated with tuberculosis, visualization studies after phrenic nerve crush reveal some upward displacement and crowding of pulmonary vessels (Fig. 7). There may be slight elevation and rotation of the heart if the phrenic crush is left sided. A moderate diminution in vascularity and delay in blood

A.



B. *C.*

Fig. 3.—(J.D. No. 215) Fibrothorax left lung due to fibrocavernous tuberculosis in a 20-year-old white woman. *A*, Conventional roentgenogram. Extensive fibrosis of left lung with deviation of the heart, trachea, and mediastinum into the left thorax and cavities of the left upper lobe. *B*, Angiocardiography shows the position of the superior vena cava, the right heart chambers, the pulmonary artery and its branches, and reveals that the heart has assumed the right oblique position. The left pulmonary artery (seen on end) is markedly diminished in size, and there is no pulmonary arterial circulation demonstrable in the left lung. The elongation of the right pulmonary artery and the wide separation of the pulmonary arterial tree suggests overdistension of the lung. *C*, Angiocardiography after thoracoplasty shows return of the heart and great vessels toward the midline position. There is no overdistension of the right pulmonary arterial tree and the right pulmonary artery is no longer elongated,

flow occurs. This is evidenced by diminution in caliber of vessels and delay in opacification on the collapsed side. On the whole, these changes are less marked than those noted in thoracoplasty and pneumoperitoneum.

DISCUSSION

At postmortem examination, Auerbach noted a significant decrease in the blood supply of lungs collapsed by thoracoplasty.[11] Pulmonary arteries were found to show marked intimal thickening. Roentgenographic visualization studies of collapsed lungs by the injection of radio-opaque substances has been

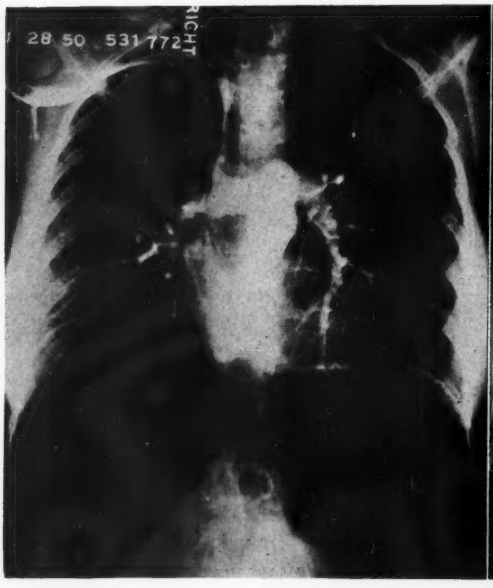


Fig. 4. Fig. 5.

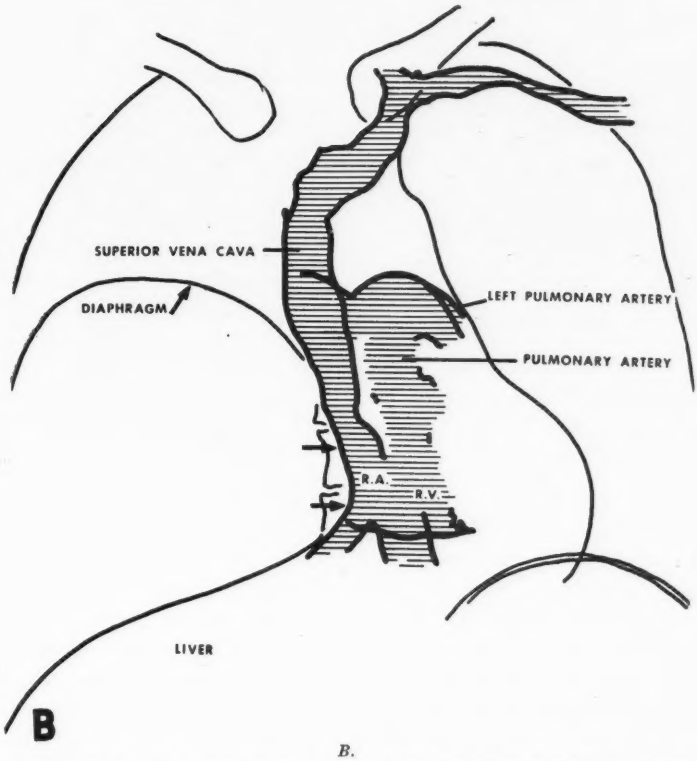
Fig. 4.—(C.L. No. 531 772) Angiocardiogram of a 24-year-old woman with fibrocavernous tuberculosis who had arrest of the far advanced disease by an effective artificial pneumoperitoneum. Heart and pulmonary vascular tree displaced upward one-third of the distance of the thorax.

Fig. 5.—(M.M. No. 550 853) Angiocardiogram showing arrest of fibrocavernous tuberculosis of the right upper lobe in a 26-year-old woman after eighteen months of treatment with artificial pneumoperitoneum. Heart and pulmonary vascular tree elevated upward by elevation of diaphragm. The right atrium is deformed.

carried out in autopsy specimens by Birkelo and Brosius.[2] In lungs collapsed by thoracoplasty they, too, noted diminished vascularization. The angiocardiographic findings in living individuals herein reported are in accord with these postmortem observations.

Occasionally patients will note relief of dyspnea and tachycardia following thoracoplasty.[12, 13] Cournand and Richards[14] have indicated that in certain circumstances pulmonary function improves somewhat following this procedure. Improvement of this sort may be partly explained by the return of the heart

A.



B.

Fig. 6.—(J.S. No. 512 967) Angiocardiogram of a 33-year-old white man who had arrest of far advanced fibrocavernous tuberculosis of the right upper lobe after seventeen months treatment by artificial pneumoperitoneum and right phrenic nerve crush. *A.* Striking deformity of the right atrium by the highly elevated right diaphragm. Avascularity right lung. *B.* Tracing of A.

and great vessels toward a more normal position in the chest, as well as by the decrease in distention of the overexpanded noncollapsed lung (Fig. 3C).

Changes in position of the heart have long been recognized following thoracoplasty.[15] Unusual electrocardiographic patterns have been ascribed to these positional variations.[16] Angiocardiography permits recognition of the degree of these changes.

Pulmonary function studies in patients receiving pneumoperitoneum indicate that significant collapse of the lung occurs.[17, 18] As yet, postmortem studies of the pulmonary vascular tree in this form of collapse have not been recorded.

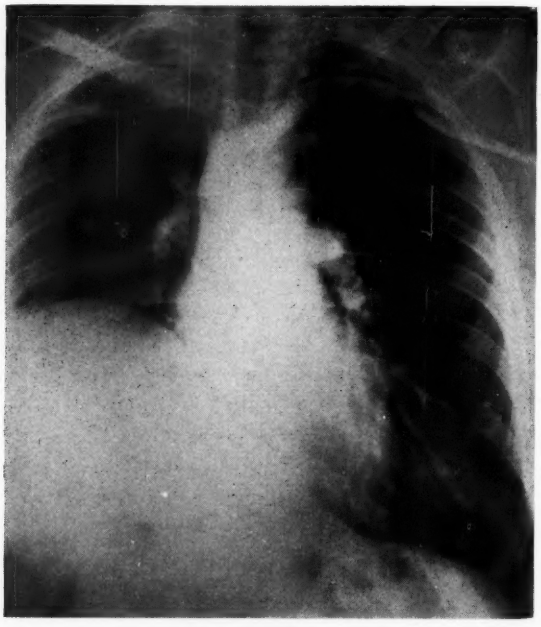


Fig. 7.—(W.M. No. 167) Angiocardiogram of a 33-year-old Negro physician with active far advanced fibrocavernous tuberculosis of the right upper lobe. Avascularity of right upper lobe and delay in filling of right pulmonary artery is apparent, as is elevation of the right leaf of the diaphragm caused by a phrenic nerve crush.

In a small number of autopsy observations there appeared to be a crowding of pulmonary vessels with diminution of vascularity in the compressed lungs. This was most marked on the side of the phrenic nerve crush.[19] In addition there was upward displacement of the heart and great vessels, as well as rotation of the heart. Similar positional changes of the heart have been studied postmortem through "windows" in the chest wall by Elwood, Piltz and Potter.[20] They correlated these positional changes with the changes noted on electrocardiograms. In pneumoperitoneum, both the positional changes and diminution in pulmonary vascularization were noted angiocardiographically.

In Fig. 6 the elevated right hemidiaphragm appears to have caused medial displacement of the wall of the right atrium and narrowing of the lumen of the superior vena cava. Peripheral dilatation of this vessel suggests interference with venous return, although absence of opacification of collateral channels suggests that this is compensated for physiologically. Furthermore, no significant elevation in venous pressure was noted either standing or lying, before or after refills in this patient. Cardiac decompensation has been reported as a rare complication of pneumoperitoneum, and then only where pre-existing heart disease has been present.[21, 22] Rotation and displacement of the heart and great vessels and diminution in pulmonary vascularity, together with interference with the venous return, like that described above, but which are not compensated for, may conceivably play a part in the mechanism of heart failure in these individuals.

The effect of phrenic nerve crush on the pulmonary vessels is not marked. Postmortem injection studies have shown that the pulmonary vessels are closer together than in lungs with normal expansion.[2] A diminution in vascularity following phrenic crush has been found experimentally.[23] These changes are in accord with those noted by contrast visualization in this report.

In all forms of collapse therapy studied angiocardiographically, diminished pulmonary vascularity of varying degree has been noted. This was most marked in artificial pneumothorax and thoracoplasty, somewhat less in pneumoperitoneum with phrenic crush, less marked in pneumoperitoneum alone, and least in phrenic crush. The controversial theories by which collapse therapy is said to be beneficial in the healing of tuberculosis[4, 24] will not be discussed here. However, the common factor of diminished vascularity noted in the forms of collapse studied is noteworthy, inasmuch as the tubercle bacillus has been shown to be a strict aerobe requiring large amounts of oxygen for life and growth.[25, 26]

SUMMARY

Angiocardiography affords a method of roentgenographic visualization of the cardiovascular structures in the living individual. The changes which occur following collapse by thoracoplasty, artificial pneumoperitoneum, and phrenic nerve crush are illustrated in patients with tuberculosis. Diminished vascularity of varying degree was common to each of these forms of collapse. Thoracoplasty, like pneumothorax, resulted in a marked diminution in opacification of the pulmonary arterial tree on the collapsed side. There was a diminution in caliber with delay and nonfilling of pulmonary vessels. Often a shift of the heart and great vessels away from the side operated upon occurred. Following artificial pneumoperitoneum the diminution in pulmonary vascularity was found to be roughly proportionate to the degree of elevation of the diaphragm. Upward displacement and rotation of the heart and great vessels was demonstrated. These effects were more pronounced when a phrenic nerve crush was added. In phrenic nerve crush alone only moderate decrease in pulmonary vascularity was noted.

REFERENCES

1. Steinberg, I., McCoy, H. I., and Dotter, C. T.: Angiocardiographic Findings in Artificial Pneumothorax, Am. Rev. Tuberc. **62**: 353-369, 1950.
2. Birkelo, C. C., and Brosius, W. L.: Roentgen Visualization of Pulmonary Arterial Circulation in Autopsy Material, Radiol. **31**: 261, 1938.
3. Pinner, M.: In Alexander, J.: The Collapse Therapy of Pulmonary Tuberculosis, Springfield, 1937, Charles C Thomas, pp. 52-69.
4. Coryllos, P. N.: How Do Rest and Collapse Treatment Cure Pulmonary Tuberculosis? J.A.M.A. **100**: 480, 1933.
5. Robb, G. P., and Steinberg, I.: A Practical Method of Visualization of the Chambers of the Heart, the Pulmonary Circulation and Great Blood Vessels in Man, J. Clin. Investigation, **17**: 507, 1938; Am. J. Roentgenol. **41**: 1, 1939.
6. Dotter, C. T., Steinberg, I., and Temple, H. L.: Automatic Roentgen-ray Roll Film Magazine for Angiocardiography and Cerebral Arteriography, Am. J. Roentgenol. **62**: 335, 1949.
7. Dotter, C. T., and Steinberg, I.: Clinical Angiocardiography: A Critical Analysis of the Indications and Findings, Ann. Int. Med. **30**: 1104, 1949.
8. Robb, G. P., and Steinberg, I.: Visualization of the Chambers of the Heart, the Pulmonary Circulation and the Great Blood Vessels in Man: Summary of Method and Results, J.A.M.A. **114**: 474, 1940.
9. Steinberg, I., McCoy, H. I., and Dotter, C. T.: Angiocardiographic Findings in Pulmonary Tuberculosis, Dis. of Chest, in press.
10. Steinberg, I., Robb, G. P.: A Visualization Study of Fibrothorax: Identification of the Cardiovascular Structures, Radiol. **33**: 291, 1939.
11. Auerbach, O.: Anatomic Changes in the Lungs Following Thoracoplasty. J. THORACIC SURG. **11**: 21, 1941.
12. Alexander, J.: The Collapse Therapy of Pulmonary Tuberculosis, Springfield, 1937, Charles C Thomas.
13. Frisch, A. V.: Beitrag zur chirurgischen therapie der lungentuberculose. Wien Klin. Wehnschr. **34**: 449, 1921.
14. Cournand, A., and Richards, D. W., Jr.: Pulmonary Insufficiency. II. The Effects of Various Types of Collapse Therapy Upon Cardiopulmonary Function, Am. Rev. Tuberc. **44**: 123, 1941.
15. Domanig, E.: Form Und Lavereranderung Der Thorakalen Organe Nach Der Thorokoplastik, Deutsche Ztschr. F. Chir. **238**: 357, 1932.
16. Leiner, G. C., and Goldberger, E.: An Unusual Case of Acquired Dextrocardia. New York State J. Med. **49**: 1073, 1949.
17. Wright, G. W., Place, R., and Princi, Frank: The Physiological Effects of Pneumoperitoneum Upon the Respiratory Apparatus, Am. Rev. Tuberc. **60**: 706, 1949.
18. Lukas, D. S., McCoy, H. I., and Dotter, C. T.: Pulmonary Function Studies in Artificial Pneumoperitoneum. To be published.
19. McCook, H. M.: Personal Communication.
20. Elwood, B. J., Piltz, G. F., and Potter B. P.: Electrocardiographic Observations in Pneumoperitoneum. Bull. Am. Acad. Tuberc. Physicians **3**: 140, 1939.
21. Fowler, W. O.: Pneumoperitoneum in the Treatment of Pulmonary Tuberculosis, Am. Rev. Tuberc. **44**: 474, 1941.
22. Anderson, N. L., and Winn, W. D.: Pneumoperitoneum and Diaphragmatic Paralysis, Am. Rev. Tuberc. **52**: 380, 1945.
23. Oyamanda, Y.: Influence of Phrenicotomy on Pulmonary Circulation (Experimental). Arch. Jap. Chir. **6**: 117, 1929, Abstracted in Zentralorgane Fur Die Gesamte Chir. **50**: 669.
24. Pinner, M.: Pulmonary Tuberculosis in the Adult; Its Fundamental Aspects, Springfield, 1945, Charles C Thomas, pp. 579.
25. Novy, F. G., and Soule, M. H.: Microbic Respiration: II Respiration of the Tubercle Bacillus, J. Infect. Dis. **36**: 168, 1925.
26. Loebel, R. O., Shorr, E., and Richardson, H. B.: The Respiratory Metabolism of the Tubercle Bacillus, Trans. 26th Ann. Meeting Nat'l. Tuberc. Assoc., 196, 1930.

SUCCESSFUL REPAIR OF AN AORTIC ANEURYSM WITH STERNAL PERFORATION

R. Adams Cowley, M.D., Herbert E. Sloan, M.D., and
Neil H. Sullenberger, M.D.
Ann Arbor, Mich.

THE repair of aneurysms has been attempted since the nineteenth century by wiring, ligation, injection, compression, coagulation, and other methods. Although erosion and perforation of the sternum are not common, we are unaware of any case other than the one described in this report that has been successfully treated after erosion of the sternum had occurred.

Attention was first directed toward the irritating properties of cellophane by Page in 1939, who wrapped kidneys of dogs to produce hypertension. Pearce, in 1940, and Harrison and Chandy, in 1943, reported the use of cellophane in the obliteration of both normal arteries and aneurysms.

The use of polythene plastic films to strengthen the walls of abnormally dilated arteries was originally suggested by Poppe and De Oliviera in 1946. They reported the results of their studies using various types of cellophane and also a new plastic film called polythene. The latter consistently caused a marked fibrous tissue action, and was used by them in the treatment of four syphilitic aneurysms of the aorta.

Yeager and one of us (R. A. C.), in 1948, confirmed the reactive properties of polythene and identified dicetyl phosphate, a stripping agent used in its manufacture, as the causative factor responsible for the fibrous tissue stimulation. These authors reported gratifying results with the use of polythene containing dicetyl phosphate in the treatment of aneurysms and recurring hernias. Abbot and others have further confirmed the usefulness of the procedure in the treatment of aneurysms.

In the case reported in this paper it was not possible completely to invest the aneurysm in polythene, the plastic selected, because of difficulties encountered in the operative approach. The neck of the aneurysmal sac was, however, completely invested at its base with 1.5 mil. polythene film* and by its unique properties, i.e., ability to produce fibroblastic proliferation with subsequent scarring and contraction, the neck of the aneurysmal sac was occluded. This presumably allowed intraluminal clotting to take place, producing the desired effect.

CASE REPORT

A. P. (No. 673847) a 38-year-old white woman, was admitted to the University Hospital with a complaint of a "throbbing lump" over the upper sternum accompanied by a dull aching pain in the back and shoulders. Approximately four years previous to ad-

From the Department of Surgery, University of Michigan.
Received for publication Sept. 5, 1950.

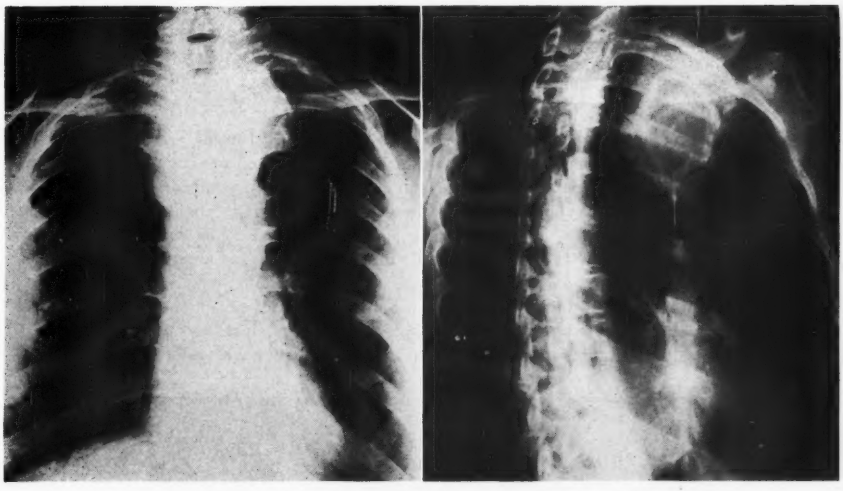
*Furnished by the courtesy of the I. E. du Pont de Nemours Company, Wilmington, Delaware.

mission she noticed a reddish lump beneath the skin over the sternum. Because of a positive serological test for syphilis, she was given a series of "hip shots" which caused the mass to disappear. The mass reappeared one year later and a diagnosis of aortic aneurysm was made. Wiring of the aneurysm was considered. On aspiration of the aneurysmal sac the patient was told that the blood had already clotted and that wiring was not necessary. Further intensive antisyphilitic treatment was given and the mass slowly decreased in size. Four months before her admission to this hospital the tumor again appeared and grew much larger than it had before. A dull aching pain developed across the back and shoulders at the same time. Six weeks before admission the pain was so severe that she was unable to raise her arms above her head. She could dress only by pulling her garments on from below. During this period the skin over the tumor had become deeply pigmented. There was no complaint of cough, dyspnea, palpitation, syncope, or hoarseness.

Fig. 1.—Photograph four days before operation. The skin over the aneurysm is shiny and pigmented. The collodion dressing covers the carotid incision for the retrograde aortogram.

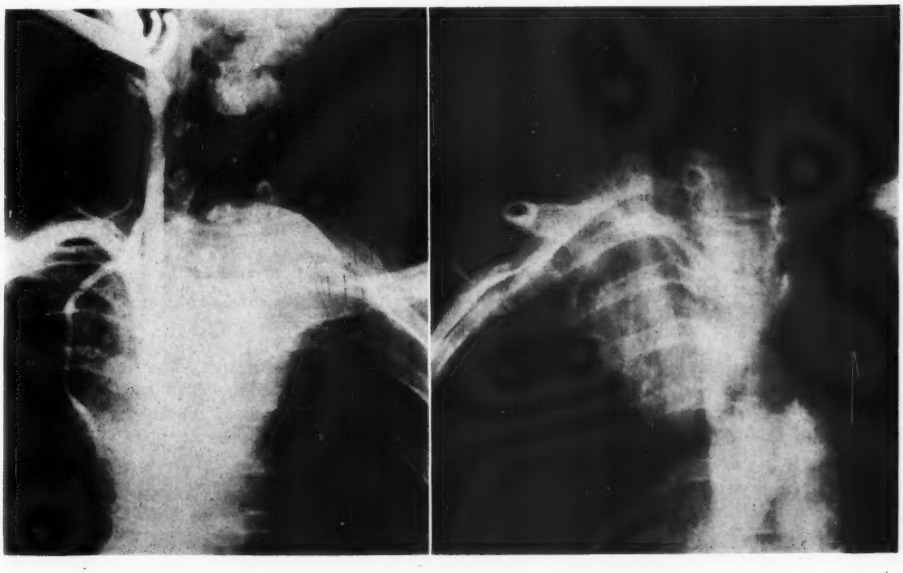
At examination, an expansile, pulsating, dome-shaped mass was noted just below the suprasternal notch, pulsation was synchronous with the heartbeat. It measured approximately 25 centimeters in circumference at its base and 5 centimeters in height (Fig. 1). The overlying skin was shiny, deep red, and pigmented. No thrill or bruit was present. The radial and carotid pulses were equal and synchronous. The Kahn complement fixation test was positive for syphilis (thirty-two Kahn units). Roentgen examinations including a retrograde aortogram and angiocardiogram (Figs. 2 and 3) showed the presence of an aneurysm arising from the anterior surface of the ascending and transverse aortic arch. It had eroded through the sternum and presented subcutaneously. The aneurysm therefore presented an hour-glass configuration; one portion being intrathoracic, the other being extrathoracic, and the constricted portion being at the level of the sternal perforation. The roentgenograms demonstrated no involvement of the great vessels arising from the aorta.

During the seven days of diagnostic procedures the aneurysm continued to increase in size. The overlying skin became thinner, and spontaneous rupture seemed imminent.



A. *B.*

Fig. 2.—(*A*). Frontal roentgenogram shows the mediastinal mass which was believed to involve the innominate artery. (*B*). Demonstrates the sternal defect. The attempt at new bone formation around the edges of the sternal perforation gives a ringed appearance.



A. *B.*

Fig. 3.—(*A*). Retrograde aortogram shows that neither the innominate, the right common carotid, nor right subclavian arteries are involved in the mediastinal mass. The right internal mammary artery is displaced laterally by the aneurysm. (*B*). Angiocardiogram shows the contrast material passing from the aorta into the aneurysm. The right innominate artery and the left carotid and subclavian arteries are not involved. The ascending aorta is approximately twice as wide as the descending aorta.

On Jan. 6, 1950, under endotracheal nitrous oxide, oxygen, and ether anesthesia, a free pleural cavity was entered after removal of the fifth right rib posterolaterally. The lung was retracted inferiorly, and a definite bulge of the mediastinum was noted above the hilum. Palpation of this area disclosed no marked pulsations, but a firm large aneurysm filling most of the superior mediastinum could be outlined and traced to a point beneath the sternum. The mediastinal pleura was incised over the mass, and the superior vena cava was found to be markedly adherent to it. A number of small veins were ligated as the superior vena cava was freed from the aneurysm. The superior vena cava was retracted laterally and posteriorly, and the dissection was carried about the base of the aneurysm and ascending aorta. The ascending aorta was found to be considerably larger than normal, and measured 4 to 5 centimeters in its greatest diameter. The aneurysm arose from the anterior portion of the ascending aorta as it joined the transverse portion of the arch. An attempt was made to free the posterior surface of the aneurysm from the trachea. A soft laminated clot containing flecks of calcium was encountered, and the attempt was quickly abandoned. The left innominate vein was found to be partially

Fig. 4.—Photograph four months after operation. A small portion of the skin is still pigmented over the previous site of the aneurysm. The sternal defect had filled in with scar tissue of a firm consistency. No roentgenographic evidence of new bone formation has as yet appeared.

compressed immediately posterior to the aneurysm and was dissected free. The innominate artery was adherent to the aneurysm except at its point of origin. The left common carotid and left subclavian arteries were not identified. The neck of the aneurysm was completely freed by digital dissection. The neck measured approximately 6 to 8 centimeters in its greatest diameter, and seemed to arise from almost the entire length of the transverse arch of the aorta. The anteroposterior diameter of the aneurysm at this point measured 4 centimeters. It was impossible to expose the left side of the aneurysmal sac because of its inaccessibility in the left chest.

We decided to wrap the neck of the aneurysm at its origin from the aorta in the hope that the contraction and fibrosis produced by the polythene would produce intravascular clotting. If this did not prove to be completely successful, it was planned later to wrap the left side of the sac through a left-sided approach. Four one-inch wide strips of 1.5 mil. polythene film were passed around the base of the aneurysm at its attachment to the aorta and sutured superficially to the wall of the aneurysm. The exposed right

lateral wall of the sac was wrapped from the sternum anteriorly to beyond the superior vena cava posteriorly. Approximately two-thirds of the aneurysm was thereby covered with polythene strips which were held in place with interrupted sutures of No. 0000 silk. The mediastinal pleura was partially approximated over the exposed area, and 500,000 units of penicillin and one gram of streptomycin in 10 c.c. of distilled water were placed in the pleural cavity. A water-sealed drainage tube was inserted, and the incision was closed.

The postoperative course was essentially uneventful. The drainage tube was removed thirty-six hours after operation. Ten days after operation the subcutaneous portion of the aneurysm had decreased slightly in size, although pulsations were still present. The patient was discharged from the hospital on the fifteenth postoperative day. She returned for re-examination twenty-six days after operation. The pain in the back and shoulders had completely disappeared. The subcutaneous portion of the aneurysm was grossly smaller, and measured 19 centimeters in diameter and 3 centimeters in height. The overlying skin was of a better texture and color. It had lost its previous shiny appearance. There were no pulsations, and the mass felt soft and cystic. These observations supported the belief that clotting had occurred within the aneurysm. Thirty-five cubic centimeters of yellowish brown serum was aspirated, and the sac collapsed to one-third its previous size. The skin could be indented, allowing the circular edge of the sternal defect to be palpated. The patient was advised to return in two months.

On her second visit four months after operation the bulge had entirely disappeared and the skin over the sternum was flat (Fig. 4). The bony defect in the sternum had been replaced with firm resistant scar tissue. There was no back pain or limitation of shoulder motion. The patient had resumed light household duties.

CONCLUSIONS

1. Polythene containing dicetyl phosphate, because of its fibrous tissue excitant characteristics, was utilized successfully in the treatment of an aortic aneurysm with sternal perforation.

2. The wrapping of aneurysms with strips of polythene offers a suitable method of treating aneurysms which, because of their position, friable walls, and close proximity to great vessels and vital structures, make other methods hazardous.

3. Using polythene strips is superior to using whole sheets of polythene, as it allows closer approximation of the film to all parts of the vessel wall to be covered.

ADDENDUM

On Oct. 9, 1950, the patient was again examined in the outpatient clinic. The mass had not reappeared and the sternal perforation had further decreased in size. Roentgenograms demonstrated a further decrease in size of the superior mediastinal shadow.

REFERENCES

1. Page, I. H.: The Production of Persistent Arterial Hypertension by Cellophane Perinephritis, J. A. M. A. **113**: 2046-2048, 1939.
2. Pearse, H. E.: Experimental Studies on the Gradual Occlusion of Large Arteries, Ann. Surg. **112**: 923-937, 1940.
3. Harrison, P. W., and Chandry, J.: A Subclavian Aneurysm Cured by Cellophane Fibrosis, Ann. Surg. **118**: 478-481, 1943.
4. Poppe, J. K., and De Oliveira, R.: Treatment of Syphilitic Aneurysms by Cellophane Wrapping, J. THORACIC SURG. **15**: 186-195, 1946.
5. Yeager, G. H., and Cowley, R. A.: Studies on the Use of Polythene as a Fibrous Tissue Stimulant, Ann. Surg. **128**: 509-520, 1948.
6. Abbott, O. A.: Clinical Experiences with the Application of Polythene Cellophane upon Aneurysms of the Thoracic Vessels, J. THORACIC SURG. **18**: 435-461, 1949.

THE DIAGNOSTIC VALUE OF DYNAMIC STUDIES IN ANGIOCARDIOGRAPHY. EVALUATION OF NEW RAPID TECHNIQUE

T. F. KEYES, M.D.,* C. WEGELIUS, M.D., AND J. LIND, M.D., ROCHESTER, N. Y.

DEMANDS OF THE THORACIC SURGEON

ANGIOCARDIOGRAPHY gives information as to the anatomy of the heart and the great intrathoracic vessels in a way which cannot be obtained by any other single diagnostic method. However, the method still needs improvements in some respects. The demands of the thoracic surgeon have primarily been the detection and localization of malformations of the heart. Often, however, the diagnosis must be based on indirect evidence, as in the case of shunts, when one may not see the local malformation which allows the abnormal passage of the dye, but only note the appearance of the dye in cavities opposite to the direction of normal circulation. Therefore, it is desirable to have a continuous visual registration of the dynamics of the heart giving more detailed information about its pathophysiology, thus increasing the diagnostic perimeter. Furthermore, it will be possible by this means to catch transient phenomena (e.g., the passage of dye through a patent ductus arteriosus) which might be lost by more widely spaced exposures. This is possible only with a very rapid technique. The object of this paper, therefore, is to describe the value of a very rapid method of angiocardiography capable of taking up to sixteen pictures per second which gives a continuous picture of events taking place in the heart chambers.

ROENTGENOLOGICAL POINTS OF VIEW AND TECHNICAL SOLUTIONS

Standard methods of x-ray investigation of the heart, i.e., separate x-ray films, give only lifeless anatomic or static abstractions of the continuing process, consisting of the changes in size and shape which visually manifest the dynamic function of the heart. As these dynamics naturally are not limited to the outer silhouette of the heart, attempts to draw conclusions about the actual dynamics of the heart only on the basis of changes in configuration of the silhouette (control by fluoroscopy, kymography, and electrokymography) must, to the same extent, be incomplete. Only angiocardiography can show us what actually takes place inside the heart and how the circulation hereby is influenced.

As the desirable solution to the problem of the complete demonstration of what takes place during the heart cycle lies in a continuous roentgenographic recording of both the mechanical and hemodynamic effects of the work, a nearly

From the Pediatric Clinic of Karolinska Institutet, Norrtull Hospital, Stockholm. Head Professor A. Wallgren.)
Received for publication Sept. 5, 1950.
*Fellow in thoracic surgery, Sabbatsberg Hospital, Stockholm.

cinematographic angiocardiography is the method of choice. In previous publications two of the authors[2-6] have analyzed the problem of rate of exposures high enough to guarantee a recording which enables studies of the heart dynamics, and stated that for this purpose a speed of twelve exposures per second is necessary. At this speed we may reckon that, even in infants with their high pulse rate, both full diastole and systole, as well as the intermediate stages between these extremes, will be recorded, giving satisfactory possibilities for judging the dynamics of the complete heart cycle. However, beyond this certain special arrangements are necessary for investigations with roentgenographic recording of the dynamic cardiac work.

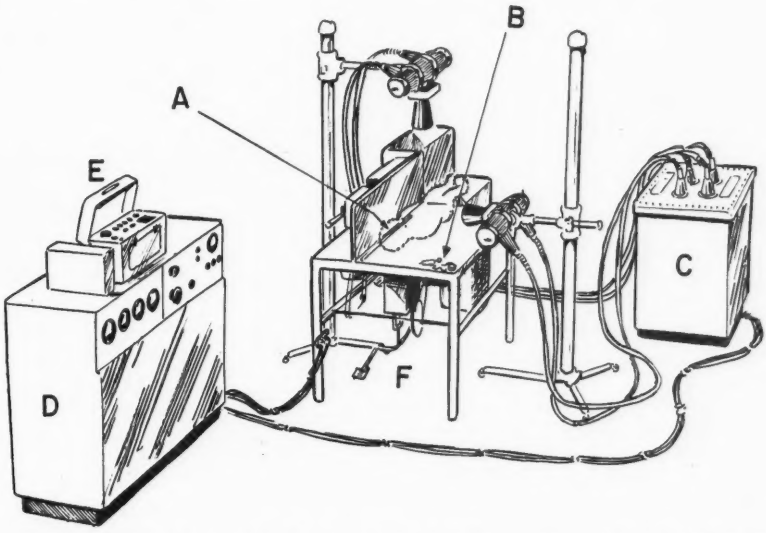


Fig. 1.—Schematic diagram of the apparatus. *A* = Roentgenographic table with cassette-changing devices. *C* = High-tension generator connected with the two x-ray tubes. *D* = Control stand.

Three-dimensional visualization of the contrast-filled heart cavities is an essential. In order to have this, photography synchronously in two planes is necessary. In addition, there must also be simultaneous ECG registration with angiocardiography in order to get an objective appreciation of the number of the pictures per heart cycle and of their duration.

Since 1949 a special built unit, which fulfills all these demands mentioned, has been in use at Norrtull's Hospital. The apparatus, which was constructed by two of the authors (C. W. and J. L.) in cooperation with the Georg Schönander Company, Stockholm, is described in detail in the literature.[3] It consists of three main parts (see the schematic Fig. 1): (A) a roentgenographic table with the cassette changing devices: (C) a high-tension generator and two x-ray tubes; and (D) a control stand. The high-tension generator is of standard type—the Schönander Dik-1000—which can deliver 1000 Ma at 100 kVP. The control

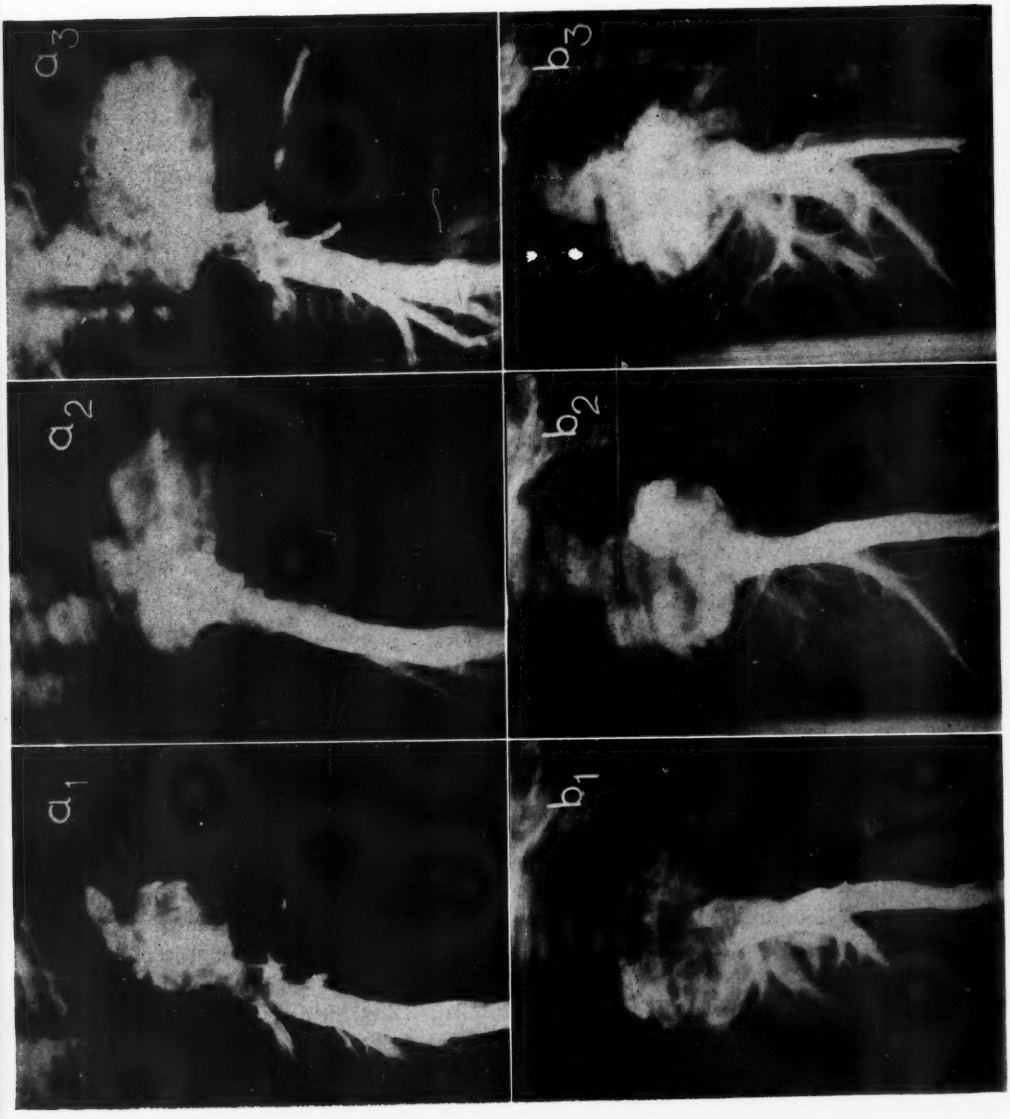


FIG. 2. (*For legend, see opposite page.*)

Fig. 2. *(For legend, see opposite page.)*

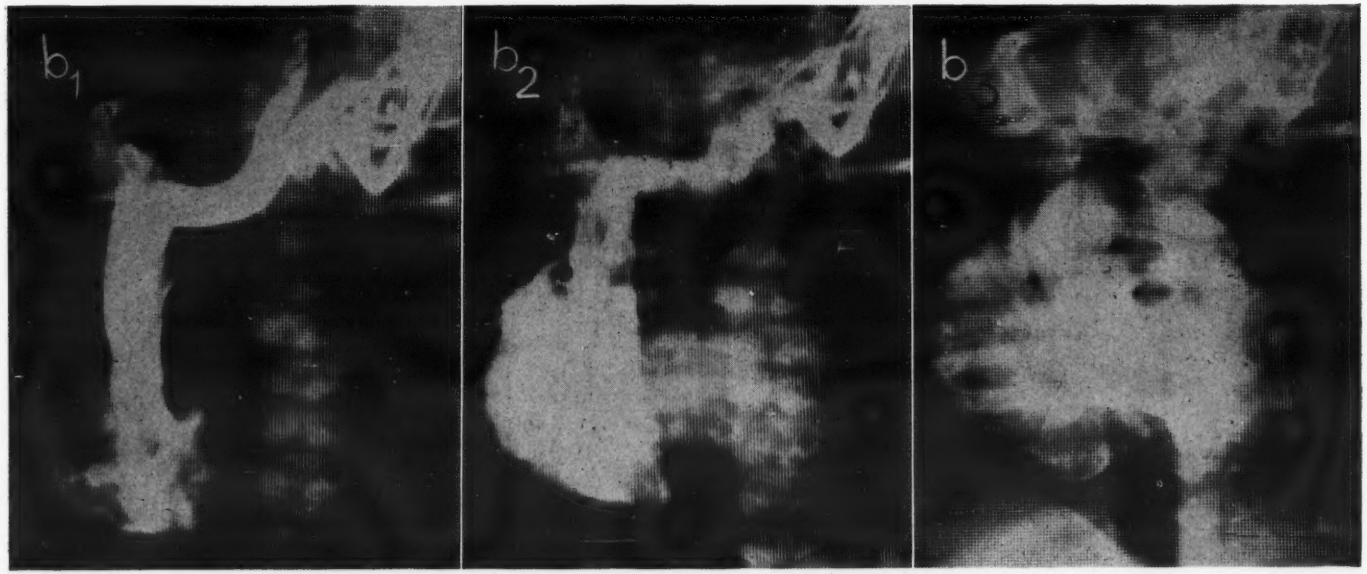


Fig. 3.

Fig. 2.—Case of tetralogy of Fallet with auricular septal defect. The angiocardiograms taken pairwise synchronously in right (a_1-a_2) and left (b_1-b_2) anterior oblique projections with 0.08 second intervals. The dye was injected in a malleolar vein. a_1-b_1: The dye is flowing from the inferior vena cava, filling simultaneously right and left auricles. a_2-b_2: The dye has passed in through the ventricles, now turned in systole and is passing out through the aorta; no pulmonary artery being visualized. a_3-b_3: The auricles in systole, the ventricles in diastole; aorta well opacified. Still no dye in the pulmonary circulation. With the auricular contraction there is a reflux of dye down into the inferior vena cava. Note the marked dissimilarity in the apparent shape of the heart in the two synchronous different projections.

Fig. 3.—Case of auricular septal defect. Injection done in the left cubital vein. Only pictures in left anterior oblique projection reproduced. (Rate—12 pictures per second.) b_1: The dye is passing through vena cava superior into the right auricle. b_2: During auricular diastole the dye can be seen flowing directly from the right into the left auricle in a stream corresponding in broadness to the size of the interseptal defect. b_3: With the next ventricular systole the dye already passes the well visualized aorta without any visible passage of dye into the pulmonary vessels.

Fig. 4.—Case of patent ductus arteriosus. Left oblique anterior projection. (Rate—12 pictures per second.) b_1: Left auricle maximally filled with the auricular appendix clearly visualized. b_2: Intermediate stage of auricular systole, left ventricle well opacified b_3: Beginning contraction of the ventricle with clear visualization of the ductus, which is no longer hidden behind the auricle, now small in contraction.

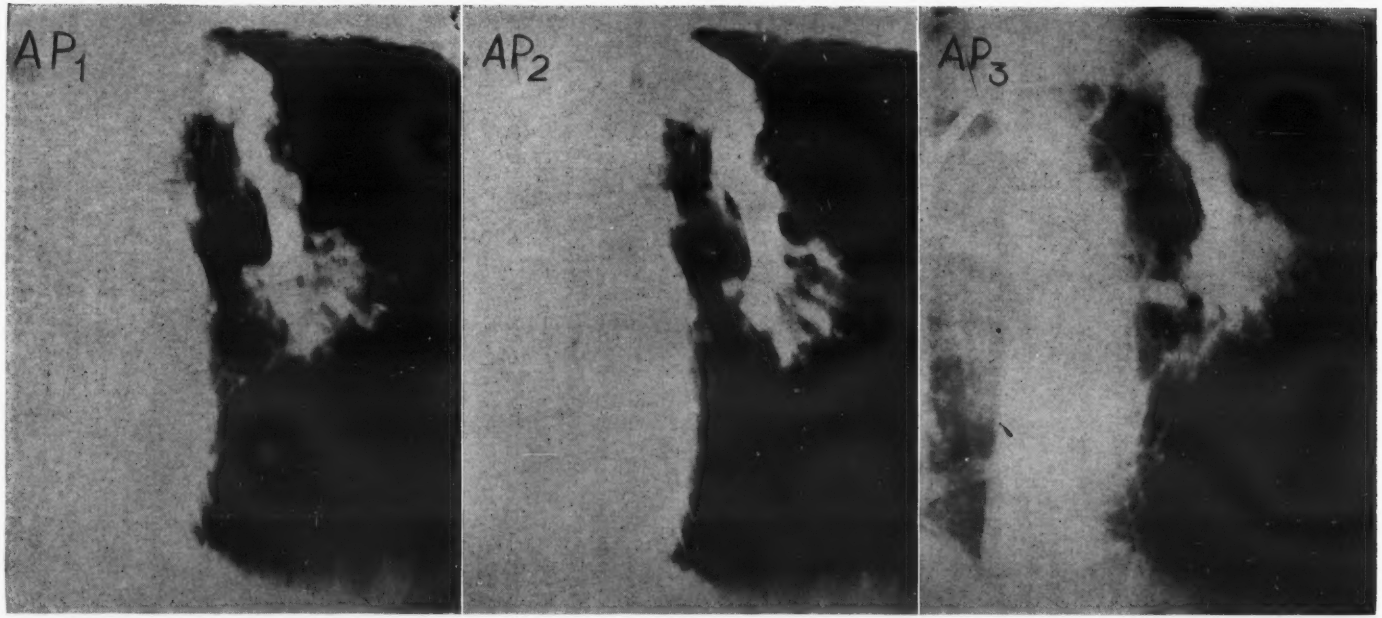


Fig. 5.—Case of arteriovenous aneurysm in the left lung. A-p projection. The dye injected through a catheter in the left main pulmonary artery. (Rate—16 pictures per second.) AP_1: The dye fills the aneurysm through an enlarged pulmonary artery. The aneurysm is situated close to the white heart shadow to the left 3 cm. above the diaphragm. AP_2: A moment later two removing pulmonary veins are visualized on each side of the supplying artery, the dye is already partly on its way back to the heart before the capillary circulation in the nonpathologic part of the lung has commenced. AP_3: The cavernous structure of the aneurysm is well visualized. Now for the first time there are signs of beginning circulation in the normal vessels.

stand consists of a timing device, control instruments and switches for kilovoltage and milliamperage. The exposure times are fixed to the periods of the supply frequency, i.e., one period 1/50 = 0.02 seconds, or two periods 2/50 = 0.04 seconds, by using electronic devices with thyratron and ignitron tubes. The cassette-changing devices are incorporated in the roentgenographic table as a single unit. There are two magazines of cassettes, one in the horizontal plane and the other in the vertical; the maximal number in each plane is seventy cassettes. By means of strong spiral springs in the bottom of the magazines the packs of cassettes are pressed against a rotating disc, in which there is a radial slit. In each revolution the disc catches the upper cassette from the magazine and brings it into position to be exposed. During the exposure all the other cassettes are protected from radiation by the motal disc. The exposed cassette is injected by a spring wheal into a collecting bag just before the disc engages the next one. The cassette gear is similar in the two planes, and the rotating discs are synchronously driven by a common motor. The cassettes are made of two sheets of fiber paper as an envelope, and the film is placed between two intensifying screens. The machine is capable of taking up to 16 pictures per second, and in two planes this means 32 pictures per second. (This is of the same rapidity as silent moving pictures.)

Figs. 2 to 5 exemplify results obtained with this apparatus by our attempts to get a continuous objective recording of the working of the heart and the intrathoracic circulation. In the legends the diagnostic findings are evaluated with special regard to increased exactness and width of application due to improvements with the new technique. From this method of procedure it would seem permissible to draw conclusions, among others, regarding such functionally important factors as the extreme and intermediate changes in size and shape of the heart cavities during the heart cycle and their reciprocal relations and duration. Furthermore, the greatly differing modes of action of the heart muscles for different heart cavities and the hydrodynamics of the fluid flows through the heart, the great vessels, and the lungs, may be elucidated, and the circulation time may be estimated with accuracy. In addition, by this method of procedure the width of the diagnostic application of angiocardiography is increased by making it possible to record phenomena, which earlier could not be intentionally visualized. By aid of the frequent sequence of exposures it is possible to show such only momentarily visualized events as the transient filling of the patent ductus and different even small shunts inside the heart.

SUMMARY

To fulfill the demand of the thoracic surgeon, who desires improvements by angiocardiography in both exactness of the diagnostic gain as well as in the width of its application, rapid roentgenographic recording of the heart dynamics is recommended. The postulates therefore are briefly discussed and the technical solutions thereto referred. The increased diagnostic application of angiocardiography regarding the heart dynamics is exemplified by results obtained with

direct serial roentgenography synchronously in two planes. Typical diagnostic findings with this rapid technique illustrating the desired improvements are evaluated in the corresponding legends.

REFERENCES

1. Axen, O., and Lind, J.: Rev. españ. pediat. **4**: 161, 1948.
2. Fredzell, Lind, J.: Ohlsson, and Wegelius, C.: Am. J. Roentgenol. **63**: 548, 1950.
3. Fredzell, Lind, J.: Wasser, and Wegelius, C.: J. Brit. Faculty Rad. **87**: 1, 1949.
4. Lind, J., and Wegelius, C.: Pediatrics 1949: Oct. 391.
5. Lind, J., and Wegelius, C.: Arch. Franc. de pediat. **6**: 338, 1949.
6. Lind, J., and Wegelius, C.: Med. III **3**: 4, 1950.
7. Steinberg, Dotter, and Andrus: Surg. Gynec., & Obst. **90**:45, 1950.

AN ANALYSIS OF VARIATIONS IN THE BRONCHOVASCULAR PATTERNS OF THE MIDDLE LOBE IN FIFTY DISSECTED AND TWENTY INJECTED LUNGS

E. A. Boyden, Ph.D., and C. J. Hamre, Ph.D.*
Minneapolis, Minn.

DURING the last decade attention has been called repeatedly to the vulnerability of the middle lobe bronchus to compression by surrounding lymph nodes. In 1943 Brock figured such enlarged nodes, and in 1950 reviewed sixty cases in which obstruction and infection of the middle lobe was attributed to active or old tuberculous lymphadenitis. In 1948 Graham, Burford, and Mayer described twelve cases in which atelectasis of the lobe with suppurative changes was due to enlargement of nodes of nontubercular origin. Again, in 1949, Paulson and Shaw presented a report of thirty-two patients with chronic atelectasis and pneumonitis of the middle lobe observed during a three-year period. Both the latter authors and Brock[6] noted that in a number of patients (one-fourth to one-sixth), bronchostenosis was limited to the lateral segment. But we know now that the "lateral" bronchus frequently supplies only half of the lateral segment, and that when the lobar bronchus divides into superior and inferior trunks (as it does in 18 per cent of cases) the territory of what is usually the lateral segment may be aerated by both trunks. It becomes exceedingly desirable, therefore, to know the variations in the bronchial pattern in order to localize the exact anatomic site of such lesions and to treat them surgically.†

MATERIAL AND METHODS

The material consists of fifty lungs from cadavers and twenty fresh specimens obtained through the generous cooperation of Dr. Franklin R. Smith. The former were dissected and carefully sketched with a view to recording both the bronchial and the vascular patterns. The latter were first injected (C. J. H.) with such colored suspensions as red lead oxide, yellow lead chromate, and cobalt blue to demonstrate the surface distribution of bronchi; then they were dissected (E. A. B.). The terminology is that used in preceding articles.

From the Department of Anatomy, University of Minnesota.
Aided by grants from the Medical Research Funds of the Graduate School.
Received for publication Sept. 21, 1950.

*Now Professor of Anatomy, University of North Dakota, Grand Forks, N. D.

†Until this year no detailed analysis of the middle lobe has appeared. Now two such studies are available. While this article was being prepared for publication in 1950, Dr. A. Ruiz Liard, Professor of Normal Anatomy in the Faculty of Medicine at Montevideo, published an excellent account of the lobe. Being written from a somewhat different point of view, his article, and this, supplement each other.

THE SURFACES OF THE LOBE

The architecture of the middle lobe is especially difficult to understand because of its irregular and variable shape, and because its two segmental bronchi are so richly branched. By comparison, the so-called middle lobe of the left lung is simple. In structure, these two are not at all similar even when the right middle has a superior-inferior pattern. This may be related to the fact that the lingular segments distribute to only three surfaces, whereas the middle lobe bronchi distribute to five surfaces.

The shape of the middle lobe in an injected specimen is shown in Plate 1. In the left-hand column the central figure shows the hilar view, after the lobe has been severed from the root of the lung. This view displays four of the five surfaces (see corresponding figure in right-hand column)—namely, the *superior* or *horizontal* (the surface bordering the horizontal fissure), the *mediastinal* (the surface contiguous with the pericardium), the *oblique* (the surface bordering the oblique or interlobar fissure) and the *diaphragmatic* surface. If this lobe be tilted upwards—the hilum remaining fixed (top figure)—the fifth or *costal* surface comes into view. If it be tilted downward (bottom figure) the oblique and diaphragmatic surfaces are more fully exposed.

Liard recognizes only four surfaces: superior, internal (our mediastinal), postero-inferior (our oblique and diaphragmatic), and costal. He thus likens the lobe, when seen in hilar view, to an irregular triangular pyramid, the base being represented by the costal surface. This is a useful comparison, but since the diaphragmatic surface forms an obtuse angle with the oblique fissure, we believe it is necessary to recognize five surfaces.

Returning to Plate 1, the blue color in the left-hand column of figures outlines a typically lateral segment (B^4), the buff color a typical medial segment (B^5). In the right column the color has been left off of part of each segment in order to better separate the subsegments. These are B^4a and B^4b, the posterior and anterior rami of the lateral segment, respectively, and B^5a and B^5b, the superior and inferior rami of the medial segment.*

These surfaces, in turn, are subject to considerable variation. The superior surface may be very narrow or very wide, with corresponding change in the costal surface; or it is frequently fused to the upper lobe. Similarly, the diaphragmatic surface may be as extensive as the diaphragmatic surface of the lower lobe. Incidentally, the knifelike edge which separates the oblique from the mediastinal surface is named the frenum, after the name given by Churchill and Belsey to the similar ridge which marks the inferior border of the left upper lobe.

THE BRONCHIAL PATTERN

The middle lobe bronchus is a long stem which descends obliquely for some distance before it branches. In fifty cadavers its mean length was approximately 18 mm., with a range of from 12 to 26 mm. Liard gives 12 to 22 mm., with a caliber of between 4 and 8 mm. Brock[6] states that in the fifty cases in which the main stem was stenosed the obstruction was located usually from 1 to 1.5 cm. beyond its origin.

*The same names were given to these subsegments by Liard, although he presumably did not see the senior author's 1949 article[3] in which they were first suggested and employed.

The mode of branching of the lobar bronchus determines the segmental pattern. Three major types of *bifurcations* have been recognized in this study (Table I) and summarized by bronchoscopic diagrams, (Fig. 1). These are (1) the prevailing lateral-medial type, (2) the modified lateral-medial, and (3) the superior-inferior type. In addition, there is the rare *trifurcate* pattern.

1. *The Prevailing Pattern.—*

This occurs in 62 per cent of specimens and is well displayed in Fig. *A* of Plate 2. (In the lower half of the figure the reader is looking down upon the horizontal and costal surfaces. In the upper half, the lobe has been lifted up to expose the oblique, diaphragmatic, and mediastinal surfaces. The latter view is the most advantageous, and is the one used in Plate 4.)

In this specimen (*A*, Plate 2) the middle lobe stem bifurcates into lateral and medial segmental bronchi (B^4 and B^5, respectively).* The lateral divides into a posterior ramus (B^4a) which is mainly directed toward the lateral angle (B^4a1)—but which also supplies the lateral horizontal surface (B^4a2)—and an anterior branch (B^4b) which is directed obliquely downward toward the inferior angle of the lobe (compare Plate 1). The medial bronchus (B^5) divides into a superior ramus (B^5a) which underlies the anterior crest (middle figures, Plate 1)—thus distributing to both mediastinal and horizontal (as well as costal and diaphragmatic) surfaces—and an inferior ramus (B^5b) which supplies that part of the oblique surface which is adjacent to the frenum. In three-fifths of the specimens (compare #27, Plate 4) B^5b arises on the medial side of B^5 rather than from its lateral margin as in specimen *A*, hence it is designated the second or "*b*" branch; but in either case it is the inferior ramus.†

It will be noted that in the above descriptions the position and distribution of each ramus has been related to certain "landmarks" on the basis of the prevailing pattern. This is essential, if one is to recognize individual rami when they become aberrant. In general, it may be stated that variations fall into two

TABLE 1. SUMMARY OF BRONCHIAL PATTERNS (50 LOBES)

I. *Bifurcations*		
1. *Prevailing lateral-medial patterns* (B^4 and B^5)		62%
B^4a + *b* and B^5a + *b*	56%	
Minor intrasegmental rearrangements	6%	
2. *Modified lateral-medial patterns*		18%
B^4a alone	14%	
B^5a alone	2%	
B^5b alone	2%	
3. *Superior-inferior patterns*		18%
B^5a superior; the rest inferior	8%	
B^4a and B^5a superior; B^4b and B^5b inferior	4%	
B^5a and B^4a2 superior; the rest inferior	4%	
B^5b inferior; the rest superior	2%	
II. *Trifurcations* (B^4, B^5a, B^5b)*		2%

*In addition to this case, one of twenty injected specimens exhibited the following trifurcate pattern: B^4a, B^4b, B^5.

*Liard calls the medial one the ventral segment, in which respect he follows Foster-Carter. To be sure, it is ventral (or anterior), but so is one of the segments of the upper lobe. To avoid duplication and for other reasons we feel that the Jackson-Huber terminology is to be preferred.

†Because of its relation to the frenum, Melinikoff called this the marginal ramus.

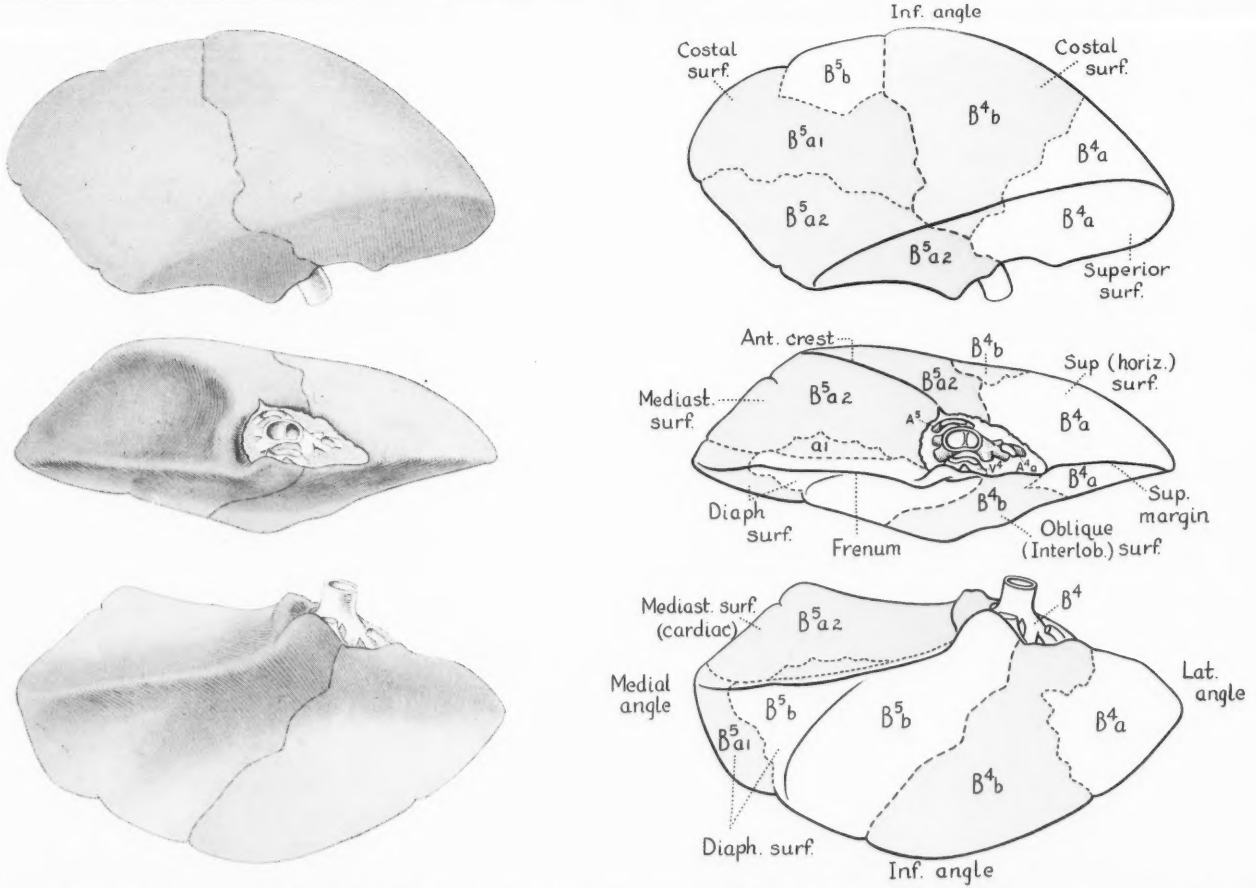


Plate 1.—*Injected Specimen 11.* This plate is designed to show the five surfaces of the lobe and the relation of the segments and subsegments to these in a typical specimen. Central figure of left-hand column illustrates hilar view of middle lobe with four surfaces visible. (See corresponding figure in right-hand column for names of surfaces and ridges.) If the lobe be tipped up—the hilum remaining fixed—the costal surface comes into view (upper figures). If the lobe be tipped down the inferior surfaces are fully revealed (lower figures). Buff color indicates the medial segment (B^5), blue the lateral segment (B^4). In right column, colors have been left off of B^5b and B^4a, the better to separate the four subsegments: B^4a and B^4b, posterior and anterior subsegments of B^4; B^5a and B^5b, superior and inferior subsegments of B^5. (Sketches rendered for publication by Lawrence B. Benson.)

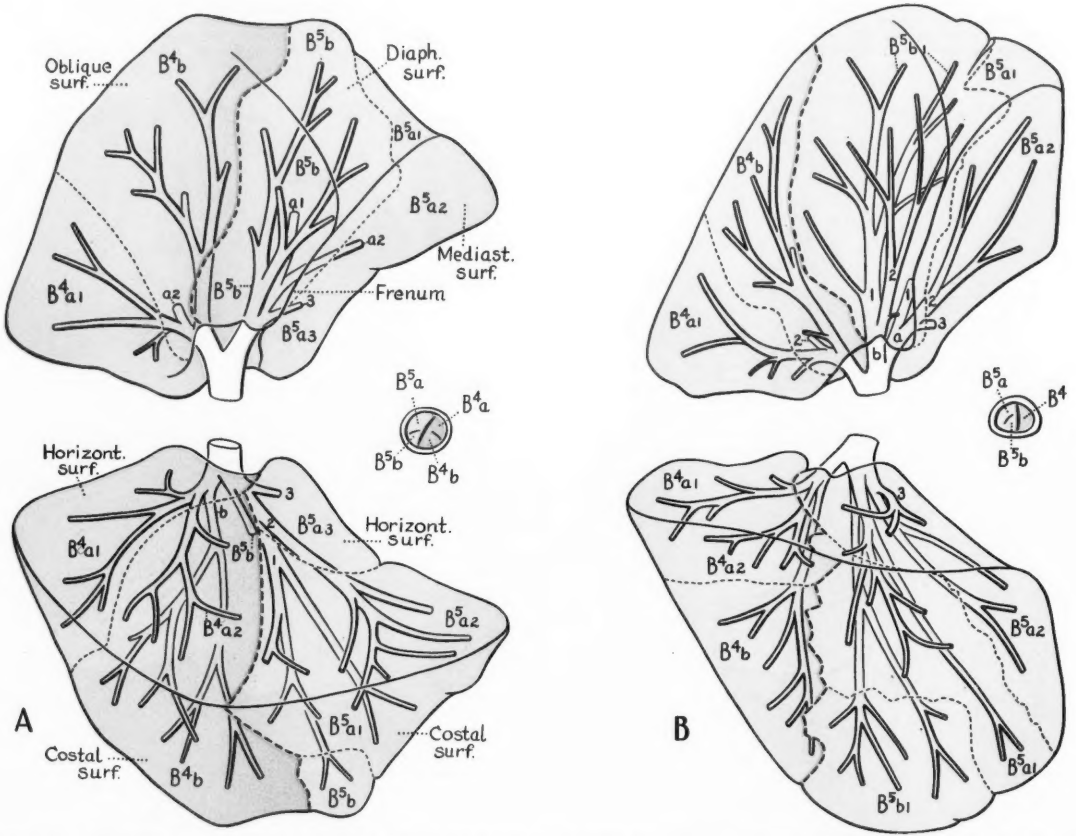


Plate 2.—*Injected Specimens 20 and 18.* Bronchi drawn as if the lobes were transparent. Color scheme same as in Plate 1. *Upper row* of figures shows inferior side of lobes, revealing oblique, diaphragmatic and mediastinal surfaces: *lower row* shows lobe from above with horizontal and costal surfaces visible. Fig. *A* illustrates prevailing pattern (see text) except that more often B^5b originates on the medial side of the medial segmental bronchus (compare No. 27, Plate 4). Fig. *B* illustrates a slightly expanded medial segment which is encroaching on the lateral segment. Small inserts show bronchoscopic view of each specimen. (Sketches rendered for publication by Lawrence B. Benson.)

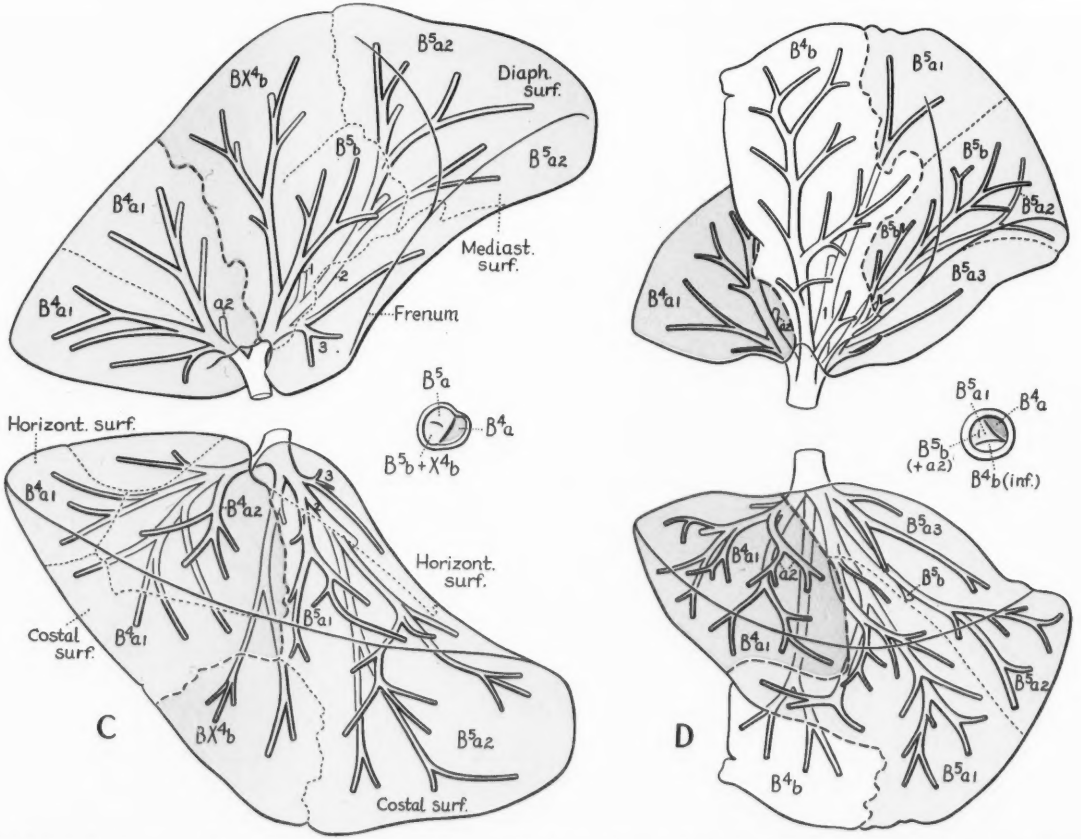


Plate 3.—*Injected specimens 15* and *6*. Fig. *C* illustrates a modified prevailing pattern in which the lateral segment is reduced to a small zone supplied by B^1a only. This is due to the fact that B^4b is a displaced bronchus, having arisen as an accessory branch of B^5b; hence the designation BX^4b. This pattern of the segregated B^1a occurred in 14 per cent of fifty specimens. Fig. *D* illustrates a rare trifurcate pattern in which segment B^1a is separated by a fissure from the other segments B^4b and B^5. Only two instances in seventy specimens were found in which the middle lobe bronchus split into three trunks. (Sketches rendered for publication by Lawrence B. Benson.)

B^5_a
B^4_b

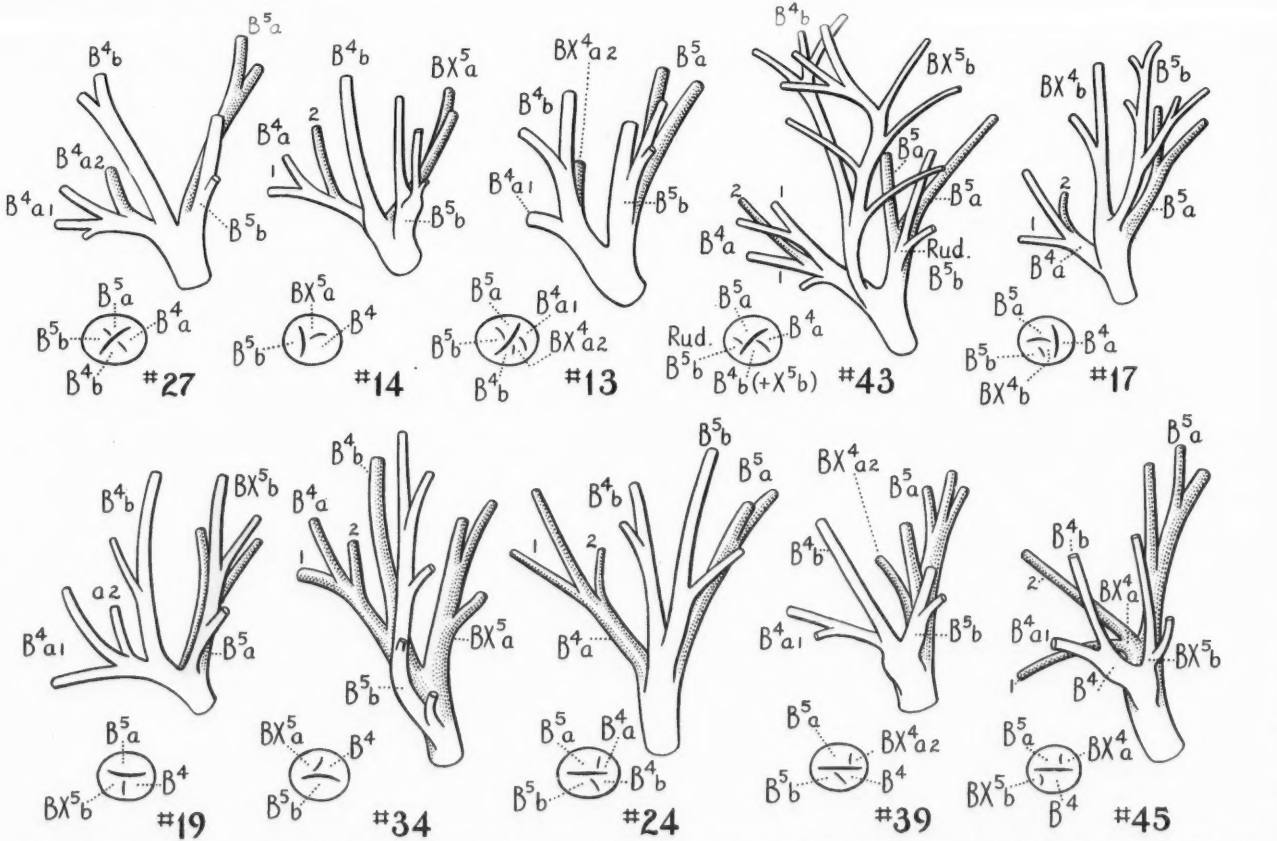


Plate 4.—A series of accurate sketches of variations of the middle lobe bronchus as seen when the lobe is elevated and dissected from its under side. *Upper row*, prevailing and modified prevailing lateral-medial patterns. *Lower row*, superior-inferior patterns. Specimens No. 27 and No. 13 are virtually normal. All others are variations. Yellow color indicates displaced bronchi. For analysis of variations, see text. (Sketches rendered for publication by Lawrence B. Benson.)

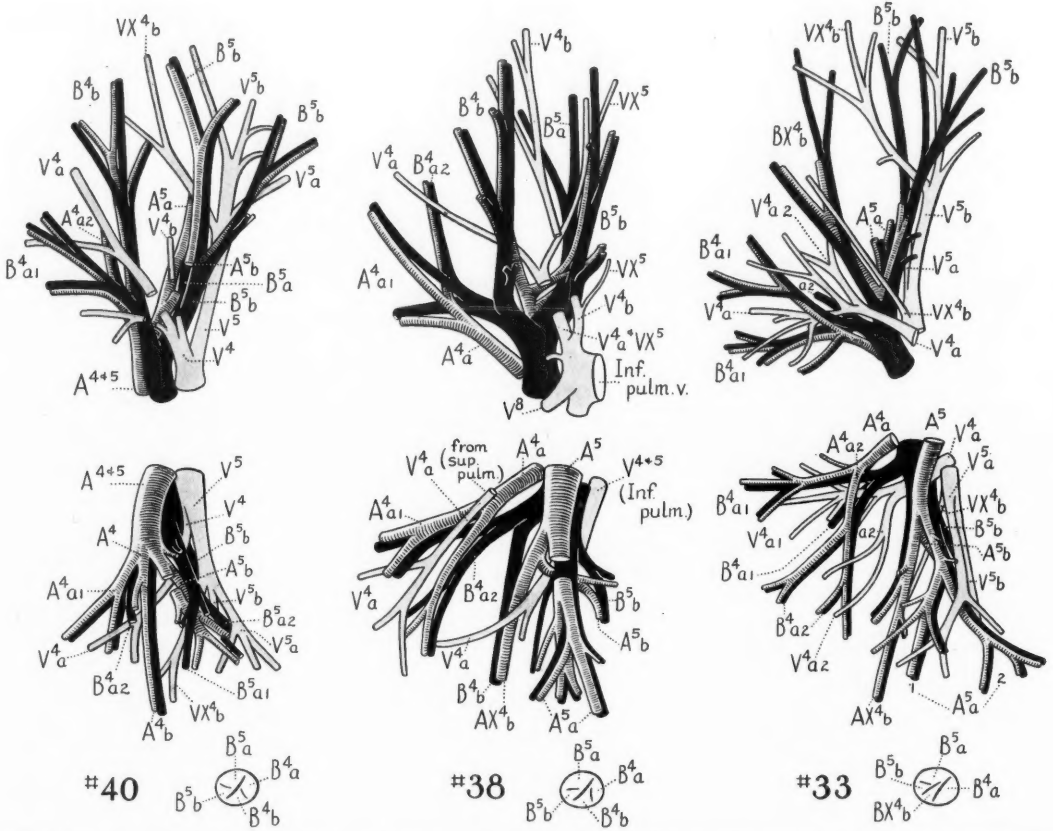


Plate 5.—Sketches of the bronchial and vascular trees of three lobes to show varying arrangements of vessels in prevailing (No. 40, No. 38) and modified lateral-medial (No. 33) bronchial patterns. *Upper row,* dissection of under side of lobes. *Lower row,* dissection of upper surface of lobes. For orientation, see Plates 2 and 3. *Black* indicates bronchi: *red,* arteries: *blue,* veins. For detailed analysis of variations, see text. (Sketches rendered for publication by Lawrence B. Benson.)

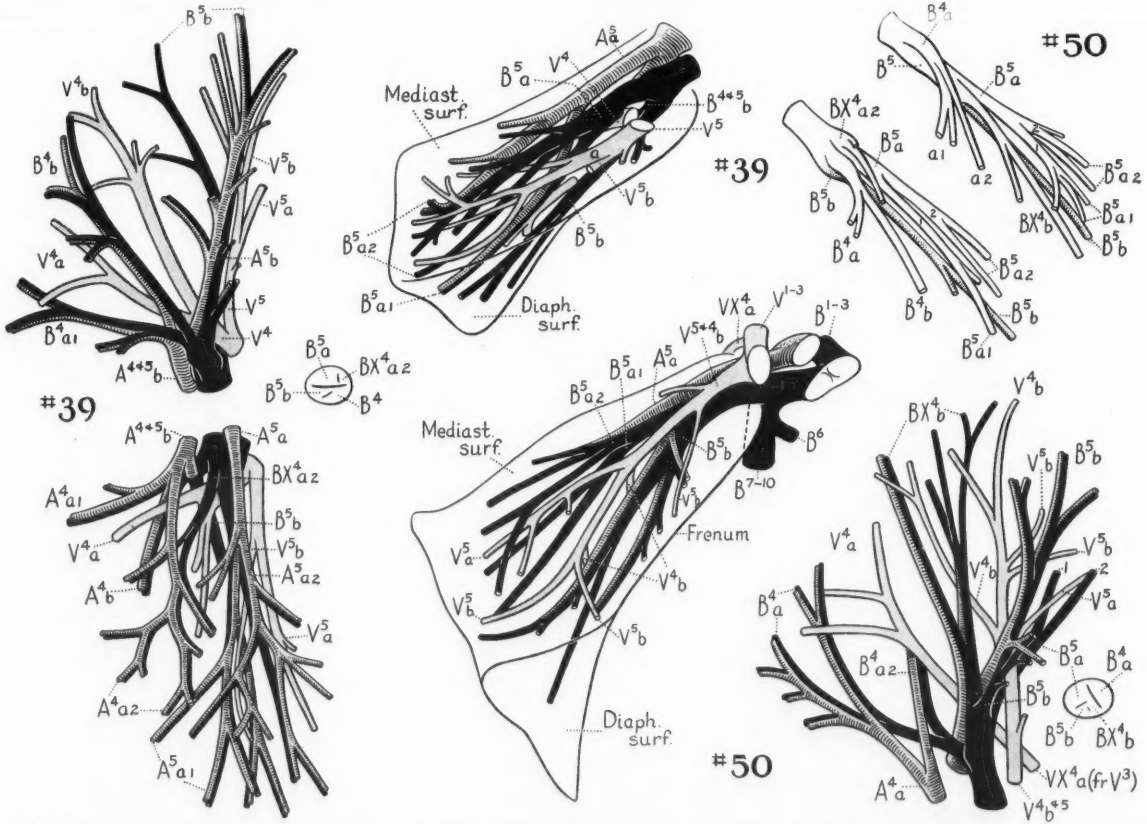


Plate 6.—Dissections designed to show relations of structures in medial and lateral views. *Specimen 39* represents a superior-inferior bronchial pattern. The two figures on the left have the same orientation as those in Plate 5. The upper middle figure displays the mediastinal surface of that specimen. Adjacent to it, on the right, is a lateral view of its bronchial tree. *Specimen 50* represents a modified lateral-medial pattern in which the middle lobe bronchus bifurcates into B^4a and a stem carrying the remaining bronchi. The lower right-hand figure is a view of the under side of the lobe; the lower central, its mediastinal surface; the upper right, a lateral view of its bronchial tree. Yellow color indicates displaced bronchi. For description of vessels, see text. (Sketches rendered for publication by Lawrence B. Benson.)

categories—a minor form of variation in which one segmental bronchus tends to spread over or encroach upon the territory of another (*B*, Plate 2) and a radical form in which there is a rearrangement of rami on the lobar tree. In the latter case the distribution of the bronchus is the key to its identity.

2. *The Modified Prevailing Pattern.*—

In this group of specimens, comprising 18 per cent of fifty lungs, the middle lobe bronchus still bifurcates into lateral and medial components, but certain rami have shifted their point of origin (Table I). The most frequent variation is the one shown at "*C*" in Plate 3 (see also #17, Plate 4; #33, Plate 5; and #50, Plate 6). In these specimens ramus B^4b originates on the stem of B^5 (or B^5b) thereby becoming an accessory or "X" branch of B^5.* We know that it is a displaced B^4b since it reaches the inferior angle, and B^4a is normal.

This important variation occurs in 14 per cent of fifty specimens (or 13 per cent of seventy, if the injected lobes are included). In such cases the lobar stem divides into a small lateral and a large medial bronchus. Brock may have unwittingly described this for he writes, "When the area supplied by the medial branch is large the lateral branch leaves it at a much wider angle, e.g. 60° or more, and in a lateral bronchogram may be seen to pass almost directly laterally (Fig. 70)." (Compare #50, Plate 6 of this article.) Incidentally, it would be interesting to know whether the lateral bronchus in this type is more vulnerable to bronchostenosis, i.e., whether it was included in those cases of atelectasis (Brock's[6] or Paulson and Smith's) that were restricted to the lateral segment. If so it might be sufficient to resect just this diminutive lateral segment.

Lucien and Beau may also have noted this pattern when they describe the middle lobe as made up of three territories, an externe (5), a postéro-externe (6) and an antéro-interne (7). In their figure of the bronchial tree, Bronchus 5 looks like a reduced lateral (our B^4a). Their bronchus 7 is obviously the medial one (our B^5), and it carries a branch (6) which has the distribution and position of a displaced B^4b. Similarly, on the left side their bronchus 5 corresponds to a proximally displaced B^4a, their bronchus 6 to B^4b and Bronchus 7 to B^5.

Less frequent modifications of the prevailing pattern are shown in the upper row of figures in Plate 4. In specimen #14, B^5b has dropped down onto the main stem from its normal position (compare #27). Consequently, the stem now bifurcates into an enlarged lateral bronchus (carrying a displaced B^5a—yellow color) and a smaller medial bronchus consisting only of B^5b.

The reverse situation is illustrated by specimen #43. Here B^5b is represented by a rudimentary twig and its territory is taken over by an expanded B^4b. Consequently the stem now bifurcates into an enlarged lateral bronchus (carrying displaced branches of B^5b—yellow color) and a smaller medial bronchus consisting virtually of B^5a.

In this connection it is necessary to point out that B^5b is at times the most difficult subsegmental bronchus to identify. The criterion, based upon prevail-

*This is in accordance with Huntington's principle that given bronchi may arise from more than one position on the bronchial tree.

ing distribution, is that it must supply that portion of the oblique surface which lies adjacent to the frenum. Sometimes, however, it is rudimentary (as in #43, Plate 4). In such cases its territory is taken over by B^4b, or it may be divided between the two, as at *D* (upper figure) Plate 3. (Note the first two right-hand branches of B^4b that reach out toward the frenum.)

Incidentally, B^5a is the most complicated of the subsegments. When the mediastinal surface is large it may consist of three main branches (numbered 1, 2 and 3, from lateral to medial side). B^5a1 is usually the deepest (see middle column of sketches in Plate 6), and often reaches the diaphragmatic surface (upper row of figures, Plate 2). B^5a2 supplies the mediastinal surface primarily (Plate 2), as well as adjacent horizontal and costal surfaces. B^5a3 is a small branch supplying the areas about the proximal end of the frenum. It is sometimes a proximal branch of B^5b (see #39, Plate 6).

3. *The Superior-inferior Pattern.*—

This radical departure from the prevailing pattern (examples of which are shown in Fig. 1 and in the lower row of figures in Plate 4), seems to be due both to a displacement and to a rotation of bronchi on the lobar stem. Brock[5] appears to have been the first to note this superior and inferior arrangement, for in discussing the upper and lower segments of the lingular division, he writes, "Occasionally the same arrangement is seen in the middle lobe as can be seen from the metal cast (of the left upper lobe) shown in Fig. 69." Liard also notes this arrangement in 8 per cent of fifty specimens (his Type III). But no one seems to have analyzed it, or to have found it so frequently.

In our material it occurred in 18 per cent of fifty specimens (Fig. 1) and exhibited a variety of forms (lower row of figures, Plate 4). The simplest type (#46, not shown in the plate) was a superimposing of B^5 upon B^4. The next (#19), represented by three specimens, may be described as a slipping down of B^5a onto the lobar stem, leaving B^5b (yellow color) as an accessory ramus of B^4. The third (#34) involved a similar process, but this time B^5b slipped down on the stem leaving B^5a (yellow color) as an accessory branch of B^4. This specimen is like the one above it (#14) except that it has rotated 90° (compare bronchoscopic views, Fig. 1).

The fourth type, represented by four specimens, presupposes a rearrangement of rami in which B^5a (always superior) and B^5b (always inferior) are joined by various other rami. In the first two specimens (#24; #42, not illustrated) all "*a*" branches are superior to all "*b*" branches (Fig. 1). In the last two (#39, #45) B^4a is split up, being represented in both upper and lower segments.

In bronchograms, the superior-inferior pattern is best detected in a lateral view. Such a view of specimen #39 is outlined in the right upper corner of Plate 6. There, B^5a (joined by a displaced B^4a2) is superimposed upon B^5b and B^4. (Four other views of #39, including a bronchoscopic one, are shown in the same plate.) This pattern should not be confused with the one in which the lateral segment is represented by B^4a (#50, Plate 6).

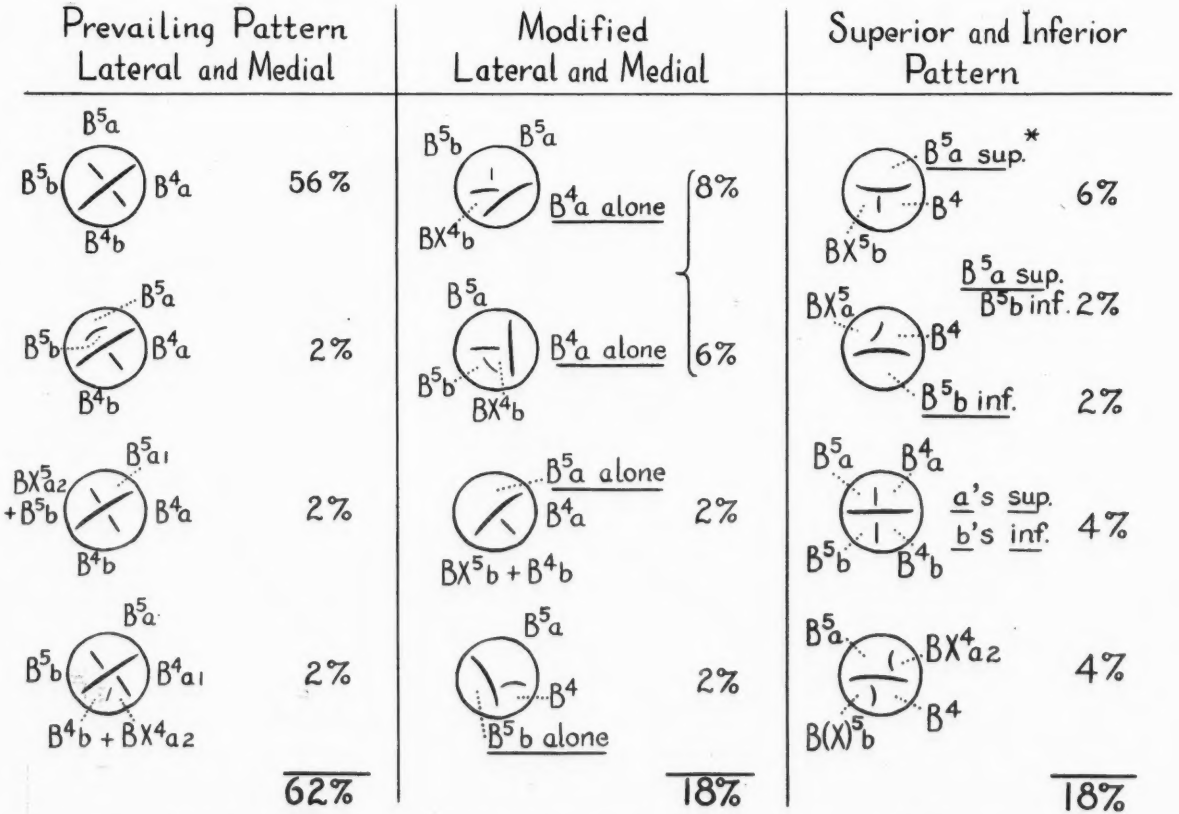


Fig. 1.—Types of bronchoscopic appearances occurring in fifty middle lobe bronchi (compare Table I). *In one of these three specimens (see Fig. 5) the inferior segment had the formula $BX^5b + B^4b$ and B^4a.

4. *The Trifurcate Pattern.*—

This is a rare variation having been encountered only twice—once in the fifty dissected, and once in the twenty injected specimens (a total of 3 per cent). Liard found one in fifty specimens (2 per cent). In his case, and in one of ours, the lobar bronchus gave rise to three bronchi, namely, B^5a, B^5b, and B^4, with B^5a uppermost. Bronchoscopically, therefore, the keel was Y-shaped. The second type is shown at *D* in Plate 3, the three segments being B^4a, B^4b, and B^5. Here the Y-shaped keel lies on its side, with B^4b inferior. Also B^4a is partially separated from B^4b by a fissure, and has the appearance of an accessory lobe. A similarly placed fissure was found in one of those specimens in which the lateral segmental bronchus consisted only of B^4a. Appleton, also, mentions occasional fissures of the middle lobe which separate lateral from medial segments, but except for minor notches we have only noted those which separate B^5a from the rest of the lobe.

5. *Anomalies Accompanying Fusion of Upper and Middle Lobes.*—

There remains one gross anomaly which involves the right upper and middle lobes. It is well known that frequently the upper and middle lobes are fused, partially or wholly, along the horizontal fissure. In such cases the bronchial pattern is not disturbed, except for minor peripheral rami which cross the fissural plane. Accordingly the surgeon is accustomed to separating the lobes along the plane of the inferior vein of the upper lobe (V^2b) without risk.* In one lung, however, which was discovered in the dissecting room, a gross anomaly was observed. In this specimen (Fig. 2) the middle lobe bronchus, although correctly placed, gave rise to the anterior segment of the upper lobe (B^2) as well as to its own middle lobe segments. In addition, the middle lobe bronchus had a superior-inferior pattern (see bronchoscopic view), in which B^2 was a displaced branch of the superior segment and B^5 a displaced branch of the inferior segment. Finally, this lung had an apical fissure partially separating the apical and posterior segments (B^1 and B^3). Apparently this was a congenital fissure along the plane of an aberrant posterior vein (V^3), although it simulated the azygos lobe.†

In conclusion; the three most important types of bronchial variations are those in which the lobar bronchus gives rise to an enlarged medial and a reduced lateral segment (B^4a; 14 per cent), to superior and inferior segments (18 per cent), and to three segments (B^5a, B^5b, and B^4; or B^4a, B^4b and B^5; 3 per cent of seventy specimens).

THE ARTERIES OF THE MIDDLE LOBE

In the older accounts, only one middle lobe artery was recognized. Thus as late as 1936, Herrnheiser and Kubat merely state that "Occasionally the costal ramus [our A^4] or the axillary branch of it [our A^4a] finds direct union

*Appleton illustrates a case involving risk (his Fig. 4) in which a horizontal cleft "divides the medial part (of the lobe) into upper and lower segments," and yet is continuous with the horizontal fissure. A surgeon attempting a lobectomy through this cleft would encounter "a branching of the middle lobe bronchus far in front of the hilum."

†Brock[5] also mentions dissecting a specimen "in which the pectoral bronchus (B^2) was aberrant and sprang from the middle lobe stem."

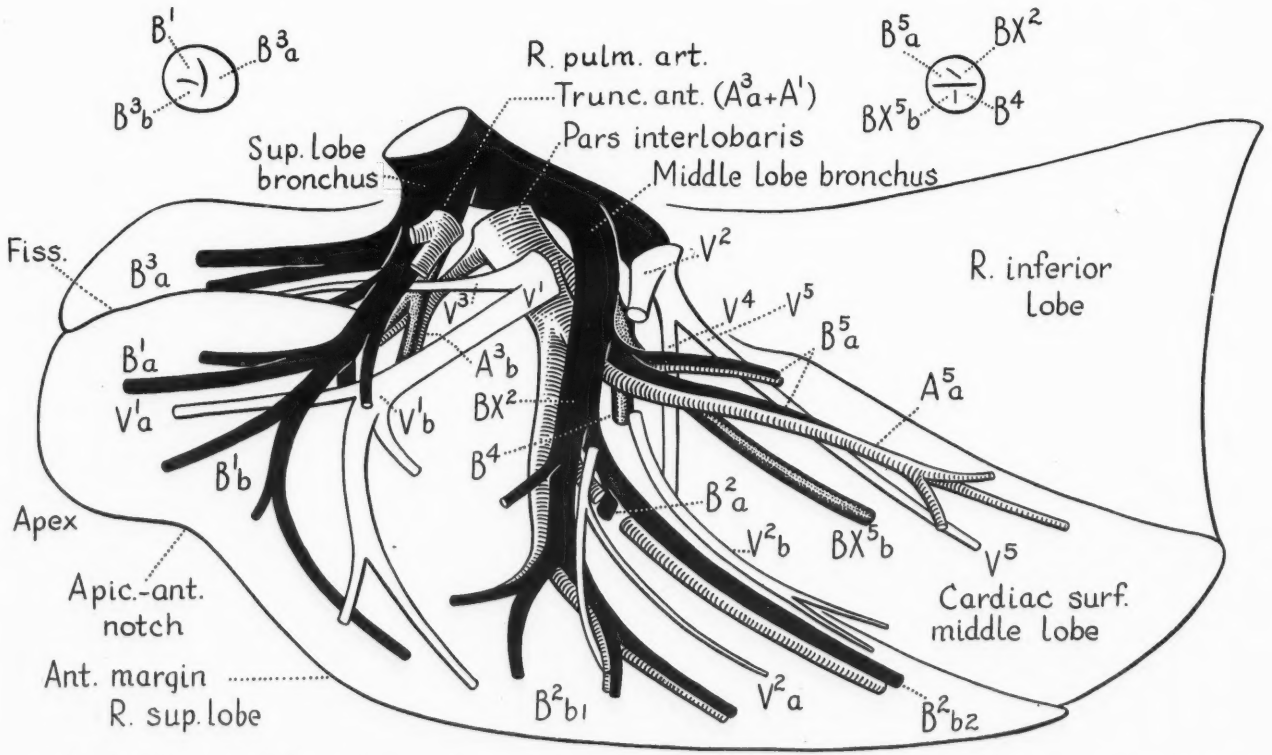


Fig. 2.—Mediastinal view of an anomalous right lung (No. 12785) in which the anterior segmental bronchus of the upper lobe (BX^2) arises as an accessory branch of the middle lobe bronchus. Bronchoscopic views of the orifices of the upper and middle lobe bronchi (see inserts) indicate the mode of branching. Note that the middle lobe bronchus has a superior-inferior pattern. The two arteries to the middle lobe pass beneath the middle lobe bronchus instead of above it. The horizontal fissure extends only a short distance toward the hilum and there is an accessory apical fissure.

with the pulmonary stem." In 1944, Appleton reversed the picture, noting that the lobe is supplied "generally by two branches" of the lower division of the right pulmonary artery. The most recent accounts confirm the frequency with which two middle lobe arteries occur.

Liard's diagrams of the right pulmonary artery (see upper row of sketches, Fig. 3) record the fact that 56 per cent of his fifty specimens had two middle lobe arteries. Lindskog, Liebow and Hales report 44 per cent in twenty-five lobes. Our fifty specimens (see figures under those of Liard) had 52 per cent with two separate arteries (Table II). In addition, Liard found a third artery (4 per cent) arising from the medial basal artery (A^7).

Liard thus recognizes an internal lobar (1), an external lobar (2), and an inferior lobar artery (3). If only one is present he still calls that the internal (Type I). If two are present, he refers to them as internal and external (Type II), or internal and inferior (Type III). However, since they supply varying portions of the lobe, it is more accurate to refer to them by numbers that correspond to the segmental or subsegmental bronchi. (See second and third row of sketches, Fig. 3.) Yet, if it is desirable to have general names, we would suggest such simple terms as the *proximal,* the *distal,* and the *distally displaced* middle lobe arteries, the third being considered accessory branches of lower lobe segmental arteries and, therefore, to be indicated by the letter "*X*" (see ♯14, ♯24, Fig. 3).

TABLE II. SUMMARY OF MIDDLE LOBE ARTERIES

I. *One middle lobe artery*			48%
1. *Bifurcation*		40%	
A^4 and A^5	22%		
A^4a and $A^{5+4}b$	14%		
A^5a and the rest	4%		
2. *Trifurcation*		8%	
A^4a, A^4b, A^5	4%		
A^4a, $A^4b^{+5}b$, A^5a	2%		
A^4a, A^5a2 and the rest	2%		
II. *Two middle lobe arteries*			52%
1. *Proximal and distal arteries*		46%	
A^5 and A^4	14%		
$A^{5+4}b$ and A^4a	26%		
A^5a and rest A^5a+^4a *and* A^5b+^4b A^5a+^4a2 and rest	6%		
2. *Proximal and distally displaced arteries*		6%	
A^{5a+4} and AX^5b (from A^7)	4%		
A^5a and $AX^{4+5}b$ (from A^{7+8})	2%		

Under Liard's types (Fig. 3) we have placed sketches of arteries from specimens shown in Plate 4. These illustrate the variable composition of the arterial types. The middle row illustrates arteries from specimens with a prevailing bronchial pattern, the lower row, arteries from specimens with a superior-inferior bronchial pattern.

The first point to discuss is the position of the middle lobe artery. It, or the proximal one (if two are present), was found to be virtually at the level (22 per cent), or above the level (26 per cent), of the superior artery of the

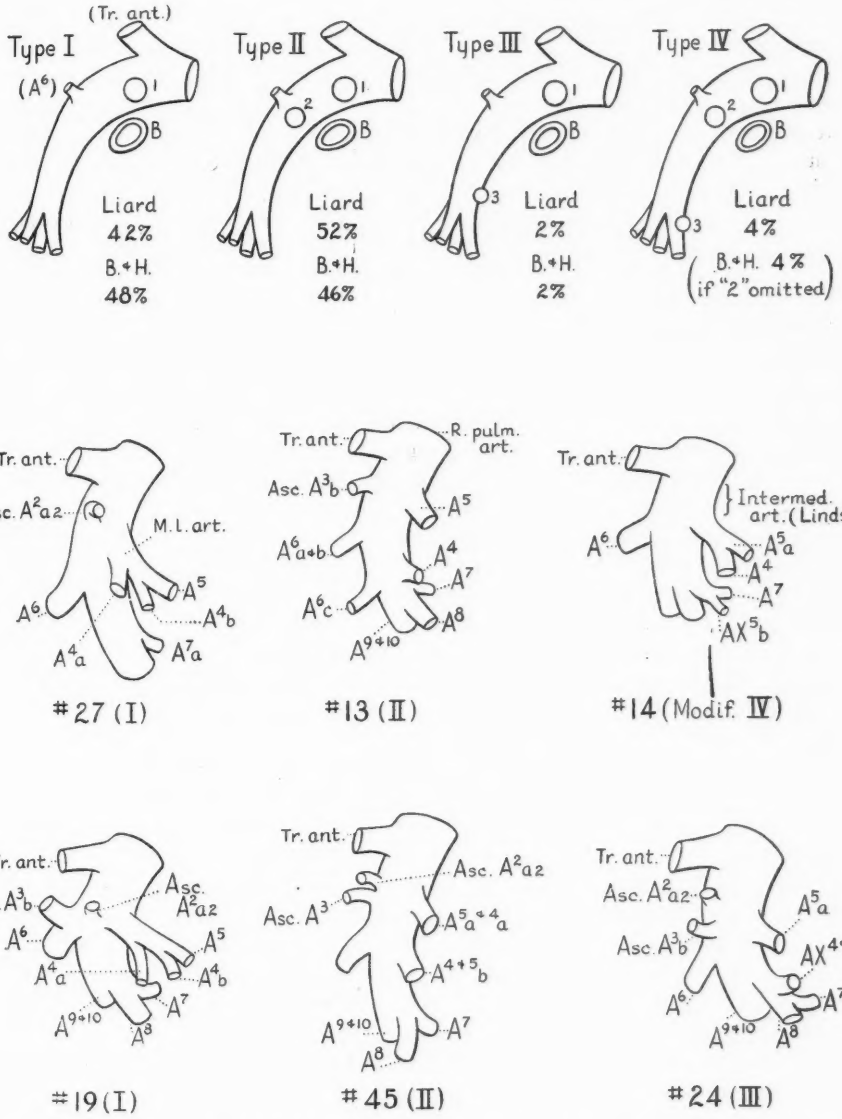


Fig. 3.—Diagrams and sketches illustrating types of variations of middle lobe arteries. *Upper row*, diagrams (after Liard) showing the four types of that author and the frequency of their occurrence in that author's fifty specimens. Under his percentages are given those of Boyden and Hamre, also based on fifty specimens. Numbers 1, 2, and 3 indicate the origin of middle lobe arteries when one, two or three are present in a given specimen. *Middle row*; right pulmonary arteries of specimens having the prevailing lateral-medial bronchial pattern (compare Plate 4, upper row of sketches). *Lower row*, right pulmonary arteries of specimens having a superior-inferior bronchial pattern (compare Plate 4, lower row of sketches). A comparison of the two series suggests that the bronchial pattern is not a factor in determining the number of middle lobe arteries. *Tr. ant.*, truncus anterior of right pulmonary artery; A^2, A^3, ascending upper lobe arteries; A^4, A^5, middle lobe arteries; A^{6-10}, lower lobe arteries.

lower lobe, A^6, or its upper ramus, $A^6a + b$ (for A^6 was divided in 14 per cent of specimens; compare ♯13, Fig. 3). If two middle lobe arteries are present the distal one is usually below, but may be at the level of A^6. This is a most important relation for surgical procedures. Lindskog, Liebow, and Hales, in their very precise account of hilar structures in the depths of the oblique fissure, state that in bilobectomy of middle and lower lobes they first ligate and divide A^6 (see Fig. 4 for orientation), then the middle lobe artery (or just the lower of the two, A^4, if two middle lobe arteries are present). After that it is possible to isolate and divide the main arterial trunk between the lowest upper-lobe artery and the highest middle-lobe artery. They call this portion the "intermediate artery" (see ♯14, Fig. 3), after Herrnheiser's "truncus intermedius."* In nineteen of twenty-five specimens (76 per cent) Lindskog and co-workers found this to vary in length between 3 and 18 millimeters. In six specimens no such segment existed; hence, they were obliged to resort to individual ligation of arteries.

While we have not made exact measurements, our sketches of fifty pulmonary arteries (compare Fig. 3) suggest that a free intermediate segment would occur in less than half of the specimens; for ascending arteries to the upper lobe (A^2a or A^3) occur below the level of the highest middle lobe artery in 12 per cent, and at the level in 40 per cent more. In a few the ascending artery originated on A^6 (6 per cent) or on A^4 (2 per cent). Including all levels, ascending arteries were present in 82 per cent. In an earlier study of fifty right upper lobes, the figure was 92 per cent.

A second point of clinical interest is the frequency of the crossing of segmental lines by the arteries of the middle lobe. In 46 per cent the arteries do not follow the bronchial patterns. This figure includes both the distribution of the two main branches of the single middle lobe artery and that of separate arteries when there are two or more. Examples of this are shown in Plate 5. In ♯38, for instance, the bronchial pattern is conventional (B^4 and B^5), but the two separate arteries are A^4a and $A^5 + X^4b$. In ♯33, the arteries have the same pattern as before, but the bronchi correspond (B^4a and $B^5 + X^4b$).

Incidentally, this A^4a and $A^5 + X^4b$ formula is the most common arterial pattern, for it occurs in 40 per cent of specimens. In this group the arterial pattern corresponds to the bronchial pattern in only one-fourth of the specimens.

The second most common arterial pattern is the conventional one, (A^4 and A^5), occurring in 36 per cent of specimens. Here the arteries correspond to the bronchi in eight-ninths of the specimens (compare ♯40, Plate 5).

The third is a miscellaneous group of 24 per cent. Here, the arterial pattern corresponds to the bronchial pattern in one-half the cases.

Finally, one might ask whether there is any correlation between the occurrence of proximal and distal middle lobe arteries and the superior-inferior bronchial pattern, but such is apparently not the case. Out of nine superior-inferior specimens, only five were supplied with two arteries, but in the remaining forty-one specimens, twenty-one had two arteries.

*Herrnheiser and Kubat defined this as that portion of the right pulmonary artery which lies between the truncus superior [the truncus anterior of Boyden][2] and the artery to the superior segment [A^6]. Lindskog's segment, therefore, is a more restricted one.

THE VEINS OF THE MIDDLE LOBE

In contrast to the arterial circulation, which in the majority of specimens was characterized by the presence of two arteries, the veins drained prevailingly into one trunk (52 per cent of specimens). In another 36 per cent there were two veins, in 12 per cent three veins (Table III).* Lindskog, Liebow, and Hales found a single vein in 64 per cent of twenty-five specimens, two veins in 36 per cent.

When a single trunk drains the middle lobe it may be designated the *middle lobe vein,* and its two chief tributaries the *lateral* (V^4) and the *medial* (V^5) rami. Each of these may have *"a"* and *"b"* branches— V^4 always has them— these lying respectively on the anticlockwise side of the correspondingly named bronchi, when seen from above (Fig. 4).

When there are two separate veins, V^4 and V^5 (or fractions or combinations of the two) both may empty into the superior pulmonary on the medial side of the middle lobe bronchus (22 per cent), or one may empty medially and the other superiorly (14 per cent). In the latter type the superior one (usually

TABLE III. SUMMARY OF MIDDLE LOBE VEINS

I. *Number of veins*			
1. *Single vein* on medial border of lobe			52%
2. *Two veins* draining lobe			36%
1) Both on medial border		22%	
2) One superior, one medial		14%	
a) Superior from superior pulmonary vein	4%		
b) Superior from V^2	6%		
c) Superior from V^3	4%		
3. *Three veins*			12%
1) Two medial, one inferior		6%*	
2) Two medial, one superior (from V^2 or pulmonary)		4%	
3) Two superior (from V^3), one medial		2%	
II. *Composition of veins*			
1. *Lateral vein (V^4)*			
1) Occurs in complete form			60%
2) Occurs in incomplete form			40%
a) V^4b a branch of V^5		31%	
b) V^4a a branch of V^5		3%	
c) Miscellaneous		6%	
2. *Medial vein (V^5)*			
1) Occurs in complete form			64%
2) Occurs in incomplete form			36%
a) V^5b a branch of V^4		15%	
b) V^5a a branch of V^4		11%	
c) Miscellaneous		10%	
III. *Position of V^4*			
1. Passing between B^4b and B^5b			36%
2. Passing superficial and inferior to B^4			34%
3. Passing between B^5b and B^5a			22%
4. Passing between $B^4a + {}^5a$ and $B^4b+{}^5b$†			8%
IV. *Specimens in which veins do not conform to bronchial pattern*			44%

*Inferior from inferior pulmonary vein (4 per cent) or left atrium (2 per cent)
†Superior-inferior bronchial pattern.

*Very small veins (such as VX^4a in Fig. 4) are not included in this enumeration.

V^4a) may drain into one of the veins of the upper lobe (compare VX^4a #50, Plate 6); rarely the median one may drain into the inferior pulmonary vein (compare #38, Plate 5).

When there are three separate veins, two of them usually drain into the superior pulmonary, on the medial side of the bronchus (Table III and Fig. 5).

In this minority group of 48 per cent having two or more veins, there were ten specimens with superior veins (20 per cent), of which seven emptied into upper lobe veins, and four specimens (8 per cent) in which middle lobe veins drained into the inferior pulmonary vein. In two lobes not in this minority group, middle lobe veins drained directly into the left atrium.

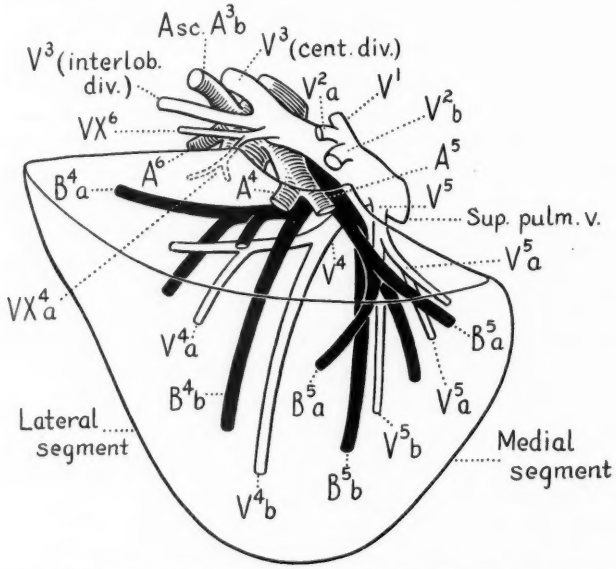


Fig. 4.—Sketch of the middle lobe of specimen 13918 to show the general relation of veins to bronchi. The vein lying on the counter-clockwise side of a bronchus is given the number of that bronchus and prefixed by the letter *V*. Note relations at hilum: the posterior vein of the upper lobe (V^2) arching above the middle lobe artery (A^{4+5}); the middle lobe bronchus lying deep and medial to the artery; the two middle lobe veins (lateral, V^4, and medial, V^5) lying, respectively, deep to B^5 and medial to it, as they empty into the superior pulmonary vein. V^4b, the interlobar ramus, separates lateral from medial segments. Note small subpleural branch (VX^4a) representing the superior incisural bronchi of Liard. V^1, V^2, V^3, upper lobe veins; A^3b, ascending upper lobe artery; A^6, VX^6, artery and accessory vein to superior segment of lower lobe (see Boyden and Scannell).

Considering the veins individually, V^4 occurs as such—i.e., with all its components—in only 60 per cent of specimens. V^5 occurs as such in only 64 per cent. Liard's statement that the former (his "principal vein") occurs in 94 per cent, and the latter (his "mediastinal vein") in 88 per cent obviously cannot refer to the whole vein, in each case. It means merely that there was a vein of undetermined composition at that place.

The apparent discrepancy in the two accounts may be explained by the fact that in 44 per cent of our specimens the veins failed to follow the bronchial pattern, for frequently V^4b (or rarely V^4a) drained peripherally into V^5 (compare

VX^4b, in #33, Plate 5); or a branch of V^5 drained into V^4 (compare VX^5, in #38, Plate 5); or the veins were multiple. Furthermore, in nearly half the specimens there was no vein which was placed intersegmentally: that is, no V^4b (Fig. 4) which could be followed surgically to the hilum to separate the lateral from the medial segment (compare #40, Plate 5) or no V^4a (such as does occur in #50, Plate 6) to separate B^4a from the rest of the tree.

In other words the venous pattern is very variable. If to these specimens we add those in which the arteries cross segmental lines we find a total of 68 per cent of specimens in which the arterial or the venous pattern (or both) does not conform to the bronchial pattern. In sum, surgical separation of segments would have been difficult, if possible, in two-thirds of our specimens.

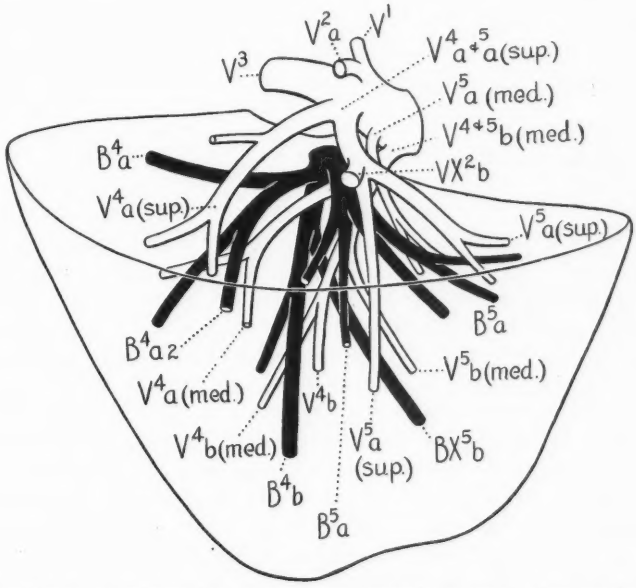


Fig. 5.—Sketch of specimen No. 11, (omitting arteries) showing three middle lobe veins in one lobe. The superior vein ($V^{4}a+^{5}a$) empties into the superior pulmonary at the point where the latter receives the upper lobe veins (V^1-V^2). Its lateral tributary V^4a sometimes terminates in V^3; its medial branch V^5a receives an upper lobe vein (VX^2b), in this specimen, but V^5a sometimes terminates in V^2. The first vein on the median side (V^5a) is subpleural running along the mediastinal surface at much the same level as the V^5a shown in the mediastinal view of V^5a in specimen No. 39 (Plate 6). The second vein on the median side ($V^{4+5}b$) occupies the position of the middle lobe vein (when only one is present). Incidentally, the bronchi are arranged in a superior-inferior pattern, very similar to that of specimen 19, Plate 4.

Lastly, since V^4 is of special interest as the vein which drains the intersegmental zone, its varying position on the oblique and medial surface of the lobe is worth noting. In 36 per cent it passed between B^4b and B^5b (#38, Plate 5). In 34 per cent, it passed inferior or superficial to B^4 (#40, Plate 5). In 22 per cent it passed between B^5b and B^5a (#50, Plate 6) and in 10 per cent between the "*a*" and "*b*" branches (#39, Plate 6). The last is characteristic of certain of the superior-inferior bronchial patterns.

Having to deal with such complexity, it is not surprising that other authors have found other ways of describing the middle lobe veins. Thus Liard divides them into two systems—the pedicular or principal and the incisural or accessory. The former is made up of the principal vein (our V^4) and the mediastinal vein (our V^5). However, he adds that V^5 is tributary to V^4. Therefore, the main trunk of his principal vein corresponds to our single middle lobe vein or to varying combinations of V^4 and V^5 located on the medial or medio-inferior side of the middle lobe bronchus. Such a principal vein, he says, has three major variations. In 60 per cent it originates under the lobar bronchus and terminates in the superior pulmonary vein. In 26 per cent it originates in front of the lobar bronchus and terminates in the superior pulmonary; in 8 per cent it originates beneath the lobar bronchus and terminates in the inferior pulmonary vein.

The second system consists of smaller veins which lie more superficially in the lobe and hence are called incisural veins. He recognizes three categories: (1) the *superior* group (36 per cent) draining the superior portion of the lateral or ventral (our medial) segment and terminating in the "sinus segment" of the upper lobe vein (compare VX^4a, Fig. 4); (2) the *internal* (medial) group (30 per cent) originating in the ventral segment and terminating in the upper lobe veins (compare $V^4a + {}^5a$, sup., Fig. 5); and (3) the *inferior* group (10 per cent) originating in the medio-inferior part of the ventral or lateral segments and terminating in the "sinus portion" of the vein of the inferior lobe. (Apparently this third category (10 per cent) differs from the third category of the principal vein (8 per cent) in the smaller size of the vein.)

The advantage of Liard's system is that it calls attention to the position and existence of a principal vein and to smaller (or larger) veins which terminate atypically. (Incidentally, his percentages of the latter are much higher than ours.) The disadvantages are that his "principal vein" is not constant in composition (and therefore a variable structure), that such a system does not relate the veins to individual bronchi and that many of the so-called accessory veins do drain portions of the middle lobe not otherwise provided for and are often important vessels: For example, VX^4a (#50, Plate 6) is an accessory superior vein emptying into V^3 of the upper lobe, yet in this specimen it is intersegmental—separating B^4a (an abbreviated lateral segment) from $B^5 + BX^4b$ (an expanded medial segment). Again, Liard would presumably call the superior $V^4a^{+5}a$ of Fig. 5 a superior incisural vein, yet it drains a large part of both segments. For these reasons we feel that the system of designating venous trunks after adjacent bronchi conveys more specific information than any other method.

SUMMARY

The present study is based upon carefully recorded dissections of fifty preserved specimens, and injection and dissection of twenty fresh specimens. Percentages, given below, are based upon the fifty specimens, unless otherwise noted.

The middle lobe is a wedge-shaped portion of the right lung having five surfaces of which the horizontal is frequently fused peripherally, or throughout its extent, to the upper lobe.

Perhaps because of its varying shape and many surfaces it is aerated by a complex and variable system of bronchi.

Bronchial pattern: Prevailingly (62 per cent), the main bronchus bifurcates into lateral (B^4) and medial (B^5) segmental bronchi. Each of the bronchi again bifurcates—the lateral into posterior (B^4a) and anterior (B^4b) subsegmental bronchi, the medial into superior (B^5a) and inferior (B^5b) subsegmental bronchi.

The chief variations are three in number. The first (18 per cent) is a modification of the prevailing pattern whereby the main bronchus divides unevenly into one subsegmental bronchus and a stem carrying the three other subsegmental bronchi. In the great majority of these (14 per cent) the segment formed by a single subsegment is B^4a. The second type of variation (also occurring in 18 per cent of specimens) is a radical rearrangement of subsegmental bronchi (or even portions of these) into a superior-inferior pattern. The third type is rare (2 per cent), consisting of a trifurcation into one segmental and two subsegmental bronchi (3 per cent of seventy specimens).

Finally, a gross anomaly is described in which the anterior segmental bronchus of the upper lobe (B^2) takes its origin from the middle lobe bronchus.

Arterial pattern: The arteries supplying the middle lobe segments arise from three sources: (1) the proximal portion of the pars interlobaris of the right pulmonary artery, (2) the distal portion, and (3) the medial basal segmental artery of the lower lobe (A^7, or the common stem of A^7 and A^8). The third category represents distally displaced middle lobe arteries. Liard ('50) found arteries from all three sources present in 4 per cent of fifty specimens. In our series of fifty, two arteries occurred in 52 per cent: proximal and distal arteries (46 per cent), proximal and distally displaced (6 per cent); and one artery in 48 per cent. In the two-artery series, the most common pattern was $A^{5+4}b$ and A^4a (26 per cent). In the single-artery series (48 per cent) the artery bifurcated most commonly (22 per cent) into A^4 and A^5, but next frequently (14 per cent) into A^4a and $A^{5+4}b$, and then (8 per cent) into three arteries of which A^4a was one. Therefore, the most common pattern (48 per cent) is that in which A^4a stands alone as a primary ramus.

In 46 per cent of lobes the arteries crossed segmental lines.

The venous pattern: One to three large veins may drain the middle lobe. 52 per cent of lobes had one vein, 36 per cent had two veins; 12 per cent three. In 44 per cent the veins failed to conform to the bronchial pattern. An intersegmental vein, furnished by V^4 occurred in about half the specimens.

Altogether, venous or arterial patterns (or both) differed from the bronchial pattern in 68 per cent of specimens. In conclusion, therefore, it may be stated that the anatomy of the middle lobe is generally unfavorable to resection of segments.

REFERENCES

1. Appleton, A. B.: Segments and Blood-vessels of the Lungs, Lancet **2**: 592-594, 1944.
2. Boyden, Edward A.: The Intrahilar and Related Segmental Anatomy of the Lung, Surgery **18**: 706-731, 1945.

3. Boyden, Edward A.: A Synthesis of the Prevailing Patterns of the Bronchopulmonary Segments in the Light of Their Variations, Dis. Chest. **15:** 657-668, 1949.
4. Boyden, Edward A., and Scannell, J. Gordon: An Analysis of Variations in the Bronchovascular Pattern of the Right Upper Lobe of Fifty Lungs, Am. J. Anat. **82:** 27-74, 1948.
5. Brock, R. C.: Observations on the Anatomy of the Bronchial Tree, with Special Reference to the Surgery of Lung Abscess. Part III. The Middle Lobe, Guy's Hospital Reports **92:** 82-88, 1943.
6. Brock, R. C.: Post-tuberculous Broncho-stenosis and Bronchiectasis of the Middle Lobe, Thorax, **5:** 5-39, 1950.
7. Churchill, E. D., and Belsey, R.: Segmental Pneumonectomy in Bronchiectasis, Ann. Surg. **109:** 481-499, 1939.
8. Foster-Carter, A. F.: The Anatomy of the Bronchial Tree, Brit. J. Tuberc. **36:** 19-39, 1942.
9. Graham, Evarts A., Burford, Thomas A., and Mayer, John H.: Middle Lobe Syndrome, Postgrad. Med. **4:** 29-34, 1948.
10. Herrnheiser, Gustav, and Kubat, Anton: Systematische Anatomie der Lungengefässe, Ztschr. f. Anat. u. Entwcklngsgesch. **105:** 570-653, 1936.
11. Huntington, George S.: A Critique of the Theories of Pulmonary Evolution in Mammals, Am. J. Anat. **27:** 99-201, 1920.
12. Jackson, Chevalier L., and Huber, John Franklin: Correlated Applied Anatomy of the Bronchial Tree and Lungs with a System of Nomenclature, Dis. Chest **9:** 1-8, 1943.
13. Liard, A. Ruiz: Contribucion al Estudio de los Pedículos Pulmonares. II. Pedículo Lobar Medio Derecho, Anales Facultad de Medicina Montevideo **35:** 41-74, 1950.
14. Lindskog, G. E., Liebow, A. A., and Hales, M. R.: Bilobectomy—Surgical and Anatomic Considerations in Resection of Right Middle and Lower Lobes Through the Intermediate Bronchus, J. THORACIC SURG. **18:** 616-629, 1949.
15. Lucien, M., and Beau, L.: Anatomie Medico-chirurgicale de L'arbre Bronchique, Revue Méd. de Nancy, 15 Mai 1946.
16. Melnikoff, Alexander: Die Chirurgische Anatomie des intrapulmonen Gefässe und der Respirationswege, Arch. f. klin. Chir. **124:** 460-510, 1922.
17. Paulson, Donald L., and Shaw, Robert R.: Chronic Atelectasis and Pneumonitis of the Middle Lobe, J. THORACIC SURG. **18:** 747-760, 1949.

PARAGANGLIOMA SIMULATING CARCINOMA OF THE ESOPHAGUS

FREDERICK H. TAYLOR, M.D.
ST. LOUIS, MO.

THE paraganglioma is a rare tumor which may arise in the carotid[2, 5] and aortic bodies, the ganglion nodosum of the vagus nerve,[6] the glomus jugulare of the middle ear,[3] and conceivably in any other paraganglionic structure. Bloom[1] has reported two such tumors occurring in the aortic bodies of dogs. These slowly growing tumors are usually benign. Lattes[3] found evidence of malignancy in two of eighteen cases studied, while Le Compte[5] was unable to find any malignant changes in his seventeen cases.

Paragangliomas are composed of nests of large, polyhedral cells arranged in rosette formation. The nuclei are round and prominent, while the eosinophilic cytoplasm is clear and contains granules. No mitotic figures are present (Lattes). The tumors are quite vascular. Reticulin stains show the reticulin fibers wrapped about nests of cells; however, these fibers do not penetrate between individual cells. These tumors do not contain chromaffin, argentaffin granules or neurites. Le Compte[5] studied two tumors in his series for adrenalin content, and found none to be present.

The origin of the tumor discussed in this paper was not determined, although the microscopic picture and clinical evolution was that of paraganglioma. The interesting clinical picture presented by the patient warrants report of this case.

CASE REPORT

S. P., No. 40612 and No. 61474.—A 50-year-old white man first was admitted to Barnes Hospital on June 12, 1942. His main complaints were dysphagia and fifteen-pound weight loss of two years' duration. He had experienced no pain or regurgitation of food. However, in recent months he had noted increasing difficulty in swallowing solid foods. The general physical examination revealed no abnormalities. Barium swallow showed a constricting defect of the esophagus just below the introitus (Fig. 1). A submucosal mass in the cricopharynx with marked stricture of the lumen was seen through the esophagoscope. No mucosal lesion was visualized, and no biopsy was taken. The patient was discharged from the hospital on June 14, 1942, but returned two weeks later complaining of increased dysphagia and weight loss. On July 1, 1942, the cervical esophagus was explored. A constricting ring, which was thought to be the result of inflammation and fibrosis, was found just behind the cricoid cartilage. About one-half of this constricting tissue was removed. Microscopic sections revealed a tumor which was diagnosed as squamous-cell carcinoma of the esophagus. Between July 8, 1942, and Aug. 5, 1942, twenty-one x-ray treatments totaling 4300 r units were administered over the cervical esophagus.

The patient had no further discomfort until Dec. 15, 1944, when he returned to Barnes Hospital complaining of sore throat and hoarseness for three days, and dysphagia for one day. Esophagoscopy showed a constriction of the lumen similar to the one noted previously.

From the Departments of Surgical Pathology and Surgery, Washington University School of Medicine and Barnes Hospital.

Received for publication June 13, 1950.

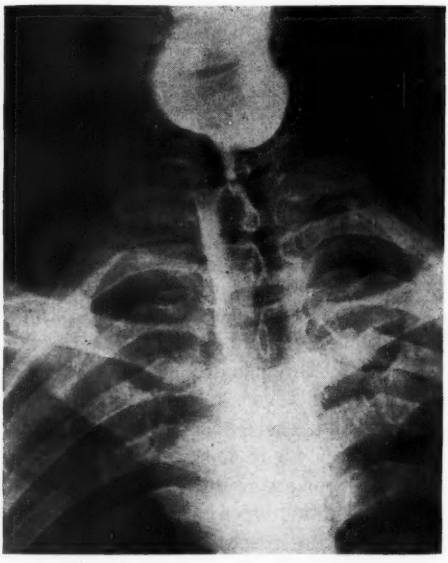


Fig. 1.—Barium swallow shows a marked stricture of the cervical esophagus.

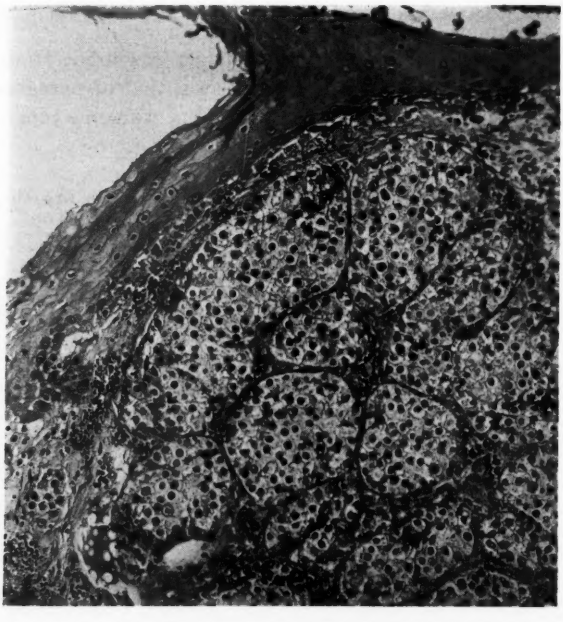


Fig. 2.—Photomicrograph ×180. The tumor is composed of nests of large polyhedral cells. The tumor shows no invasion of the overlying esophageal mucosa.

Fig. 3.

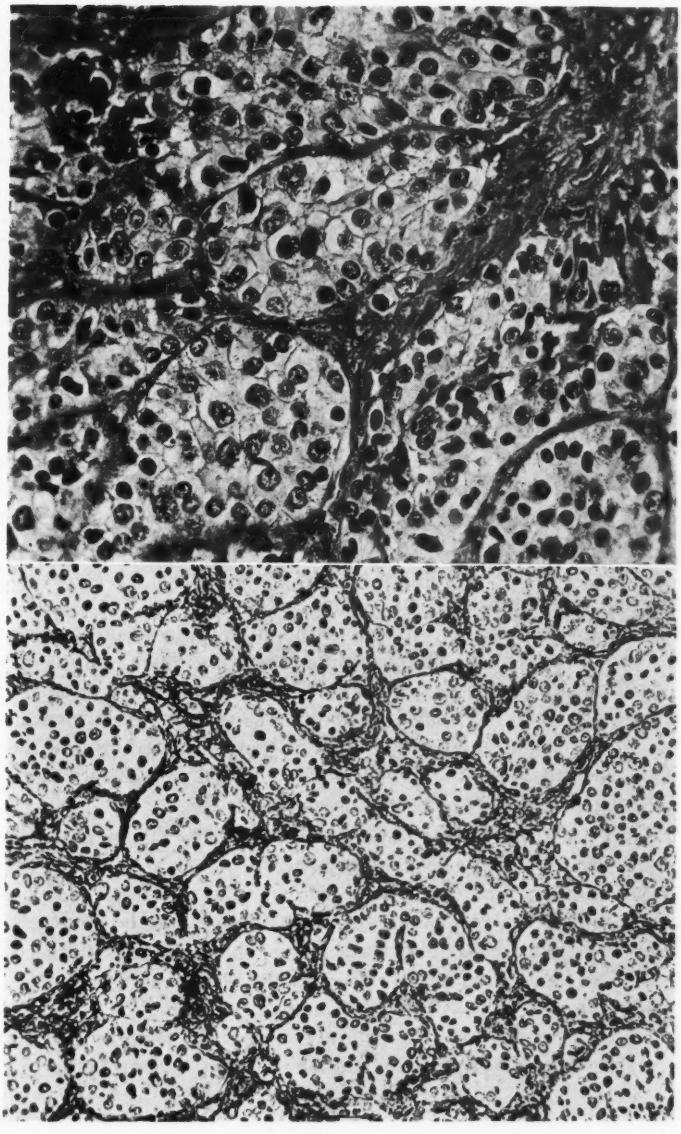


Fig. 4.

Fig. 3.—Photomicrograph ×450. High-power view of nests of tumor cells. The large polyhedral cells have large prominent nuclei and pale cytoplasm.

Fig. 4.—Photomicrograph ×230. Wilder reticulin stain. The reticulin fibers surround groups of cells but do not penetrate between individual cells.

Again the mucosa was intact, and no biopsy was taken. Numerous esophageal dilatations were required during the next two years, although the patient's general condition remained good.

The patient was readmitted to the hospital on May 17, 1948, complaining of marked dysphagia. A bougie was passed through the stricture of the cervical esophagus with much difficulty. On June 7, 1948, exploration of the cervical esophagus was carried out, and a tumor mass extending into the left side of the neck and down into the mediastinum was partially removed. A cervical esophagostomy was constructed distal to the tumor. The microscopic sections were again diagnosed as squamous-cell carcinoma. The patient was discharged on June 23, 1948, at which time he was taking esophagostomy feedings well. He returned on Oct. 18, 1948, complaining of dyspnea and respiratory distress. A tracheotomy produced relief from these symptoms.

The patient was last seen on Nov. 12, 1949, at which time he returned to have a basal-cell carcinoma removed from his face. At this time he had gained weight, and was taking feedings well.*

DISCUSSION

This case is interesting from a number of standpoints. First, it was incorrectly diagnosed as squamous-cell carcinoma on two occasions. The patient showed improvement in swallowing after the first operation and the roentgen therapy. The improvement was more likely the result of operative release of the strictured esophagus rather than the irradiation. This tumor obviously grew slowly, since the patient noted symptoms for two years prior to his first hospital admission, and was known to be well seven years after treatment. These unusual circumstances occurring in a case diagnosed as carcinoma stimulated review of the microscopic sections. The sections of the tumor showed large polyhedral cells with prominent nuclei, eosinophilic nucleoli, and pale cytoplasm. The cells were arranged in closely grouped rosettes which were separated by blood vessels and fibrous stroma. Nests of tumor cells were situated beneath the mucosa (Figs. 2 and 3), but at no point was there mucosal invasion. Reticulin fibers demonstrated by the Wilder stain were wrapped around these nests, but did not surround the individual cells (Fig. 4). No mitotic figures were seen. The diagnosis of paraganglioma was made.†

The point of origin of this tumor is obscure. The tumor may have arisen in one of the carotid bodies or in the vagus nerve. From an anatomic standpoint it would be unlikely that this tumor originated in a carotid body, although carotid body tumors can become quite large, and may even be bilateral. Lattes[3] has found paraganglion cells along the course of the vagus nerve by serial section techniques. The descent of these cells into the chest was apparently arrested sometime during embryonic life. Although a paraganglioma producing this picture has not been found in the literature, it seems possible that this tumor may have arisen from aberrant paraganglion cells in the vagus nerve.

SUMMARY

A paraganglioma which produced a nine-year history of dysphagia due to compression of the cervical esophagus is reported. This tumor simulated car-

*We are indebted to Dr. J. Barrett Brown, Professor of Clinical Surgery, for permission to report this case.

†By Dr. Lauren V. Ackerman. Dr. Raffael Lattes concurred with this diagnosis.

cinoma of the esophagus clinically, radiologically, and microscopically. The patient is alive and well nine years after the onset of symptoms, and seven years after he was first seen.

REFERENCES

1. Bloom, F.: Structure and Histogenesis of Tumors of the Aortic Bodies in Dogs, Arch. Path. **36**: 1, 1943.
2. Harrington, S. W., et al.: Tumors of the Carotid Body, Ann. Surg. **114**: 820, 1941.
3. Lattes, R., and Waltner, J. G.: Nonchromaffin Paraganglioma of the Middle Ear, Cancer **2**: 447, 1949.
4. Lattes, R.: Personal communication.
5. Le Compte, P. M.: Tumors of the Carotid Body, Am. J. Path. **24**: 305, 1948.
6. Stout, A. P.: The Malignant Tumors of the Peripheral Nerves, Am. J. Cancer **25**: 1, 1935.

PRIMARY SOLITARY NEUROGENIC TUMORS OF THE LUNG

WALTER DIVELEY, M.D., AND ROLLIN A. DANIEL, JR., M.D.
NASHVILLE, TENN.

PRIMARY solitary neurogenic tumors of the lung are rare but such tumors are occasionally found in other portions of the thorax, most frequently in, or adjacent to, the posterior mediastinum. Neurogenic tumors in, or near, the posterior mediastinum may have an hourglass or dumbbell configuration with a portion of the tumor lying in the spinal canal. These tumors may arise from nerve elements within the mediastinum, the intervertebral foramina, or the vertebral canal. Heuer[7] has pointed out that this type of tumor is a relatively common one. Solitary tumors of nerve origin are much less frequently found in the anterior mediastinum; of the 123 intrathoracic neurogenic tumors reported by Kent, Blades, Valle, and Graham,[10] only four were found in this location. One of these arose from the phrenic nerve. Blades[2] reported 29 primary nerve tumors within the thorax; none was located in the anterior mediastinum. Keller and Callender[9] removed a neurofibroma from the left chest which was attached by pedicles to the pericardium and to the visceral pleura over the lower lobe of the lung; they believe the tumor arose from the phrenic nerve. Solitary neurogenic tumors located in lateral portions of the thorax and arising from intercostal nerves have been reported by Harrington,[6] Cutler and Gross,[4] and by Touroff and Sapin.[15]

Bartlett and Adams[1] have described a primary solitary neurogenic tumor in the left hilar region which was firmly attached to the left bronchus distal to the main bifurcation. Pneumonectomy was performed and the patient made an uneventful recovery.

In 1940, Rubin and Aronson[14] described a patient who at autopsy was found to have multiple tumor nodules in and on the surface of both lungs; microscopically these tumors proved to be neurofibromas. There was no evidence of generalized Von Recklinghausen's disease. Touroff and Sapin[15] have recently reported the surgical removal of a solitary neurofibroma from the apex of the right lower lobe; the tumor was well encapsulated and was removed from the lung parenchyma without difficulty. In a review of the literature no other report of a solitary neurofibroma of the lung was found.

We have recently observed, in the Vanderbilt University Hospital, a patient with a solitary neurofibroma of the lung. Because of the rarity of such a finding this case is reported.

From the Department of Surgery, Vanderbilt University School of Medicine.
Received for publication June 15, 1950.

CASE REPORTS

CASE 1.—J. D. K., a 35-year-old white laborer, was first seen in the Out-Patient Department on Nov. 28, 1947, because of a history of nervousness of one year's duration and of vague aching pain in the left shoulder region, the interscapular region, and the left anterior chest. The discomfort was not influenced by respiration or physical activity; he noted that during periods of anxiety the pain became more severe. There had been no cough, sputum, hemoptysis, or fever. He had lost twelve pounds in weight. The past history was not contributory.

Physical examination revealed a slender, anxious man of 35 years, who was in no discomfort. The eyes, nose, throat, and neck were normal. Examination of the thorax, the abdomen, and the extremities revealed no abnormalities.

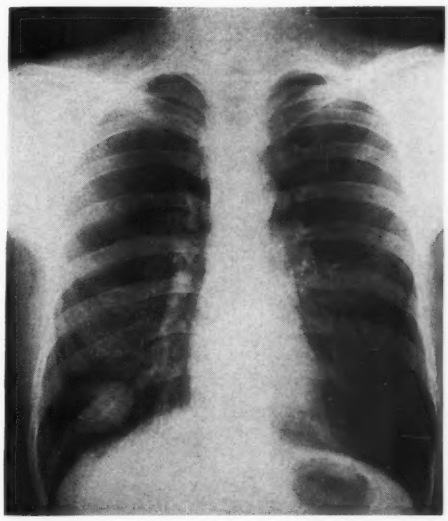


Fig. 1 (Case 1).—Posteroanterior view of chest to show the rounded tumor mass in the right lower lung field.

X-ray films of the chest showed a well-circumscribed, dense, ovoid mass about 5 cm. in diameter at the base of the right lung field (Figs. 1 and 2). In the lateral projection the mass appeared to be in the middle lobe. Its appearance was suggestive of a metastatic lesion. No abnormality was seen in roentgenograms of the dorsal spine. Intravenous pyelograms were normal.

The patient was advised to enter the hospital for further study and treatment; he was admitted to the Medical Service on Jan. 15, 1948. There had been no change in the physical findings. Roentgenograms of the thorax showed no change in the shadow in the right lung field. A gastrointestinal series and barium enema were done and no abnormality was found.

The final impression was a neoplasm of the right lung, probably benign.

Operation.—On Feb. 11, 1948, under endotracheal nitrous oxide-oxygen-ether anesthesia, the right chest cavity was entered through a posterolateral incision. A hard, well-circumscribed, rounded tumor mass about 4 cm. in diameter was found in the middle lobe. The remainder of the right lung was normal and no enlarged lymph nodes were palpable in the hilum or mediastinum. A right middle lobe lobectomy was performed. The pleural

cavity was irrigated with a large volume of normal saline. A soft rubber tube was placed in the pleural space and brought out through the anterior portion of the wound. The wound was then closed in layers with interrupted, fine, silk sutures.

Examination of the specimen revealed a 4 by 3 by 3 cm. firm well-circumscribed mass whose cut surface was pinkish-gray in color and had a lobulated appearance. The tumor was surrounded by a distinct fibrous capsule which peeled away easily from the surrounding lung tissue. No lymph nodes were found in the specimen.

Microscopic sections from the lesion showed a tumor composed of cells uniform in size, shape, and staining characteristics with elongated, vesicular nuclei which were arranged in whorls and in some areas aligned themselves in poorly formed pallisades. No mitotic figures were seen. The stroma was rather scanty. The diagnosis was neurofibroma of the lung (Figs. 3 and 4).

The patient's postoperative course was entirely uneventful and he was discharged on the eighth postoperative day. He was last seen sixteen months following operation. Roentgenograms of the chest showed no evidence of recurrence of the tumor.

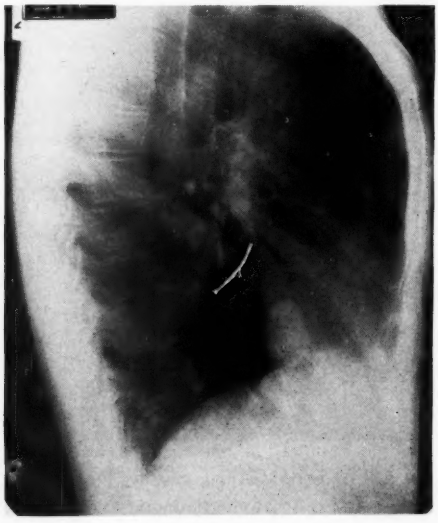


Fig. 2 (Case 1).—A lateral film of chest to show the tumor mass in the right lower lung field.

It is well known that tumors of nerve origin are often malignant. In 1935, Geschickter[5] reported the incidence of malignancy in a group of primary tumors of peripheral nerves; of 850 such tumors, which arose in parts of the body other than within the thorax, 41 per cent were found to be malignant neoplasms. A large percentage of intrathoracic neurogenic tumors are malignant. Of the 123 cases of intrathoracic neurogenic tumors reported by Kent, Blades, Valle, and Graham[10] 37.4 per cent were considered to be malignant.

In Von Recklinghausen's disease the neurofibromas may undergo malignant transformation. Hosoi[8] has discussed the incidence of this finding. These malignant neurogenic tumors may involve the lung by direct extension from the mediastinum[2, 12] or by metastasis to the lungs from a primary site outside the thorax.[11]

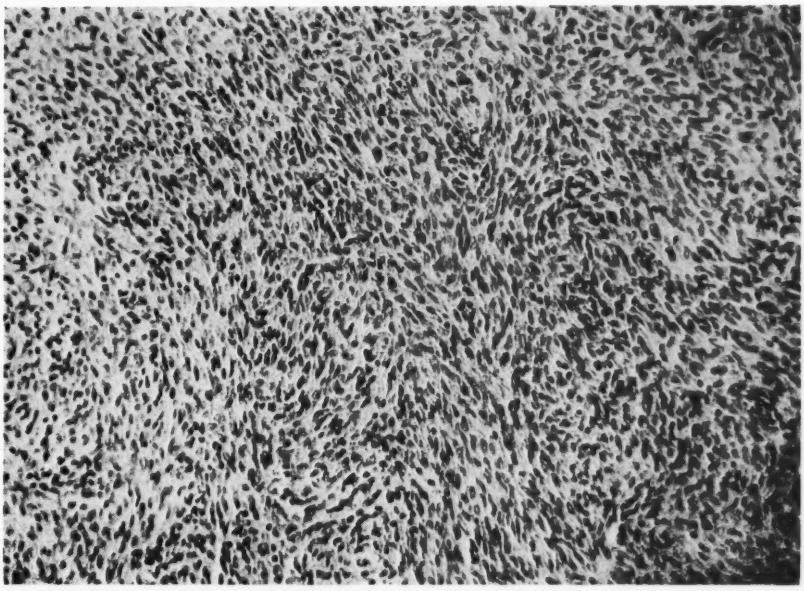


Fig. 3 (Case 1).—Photomicrograph of tumor. Low power.

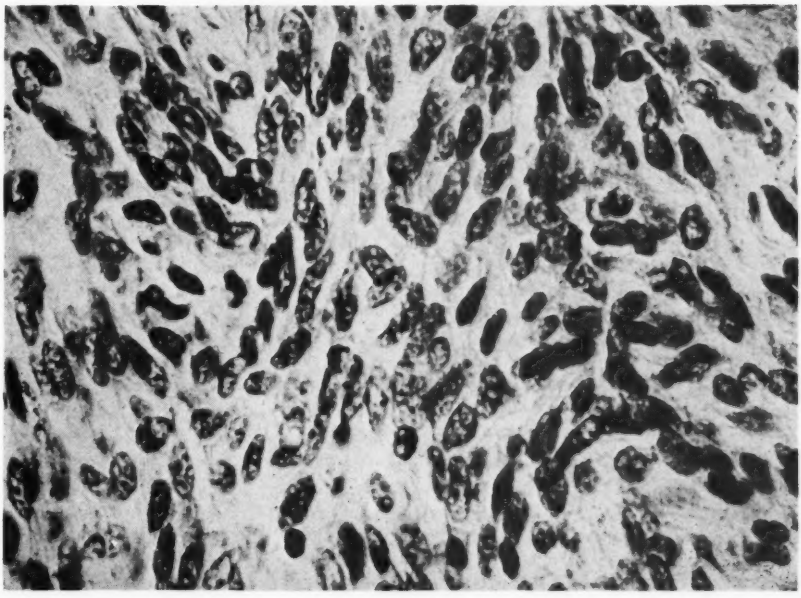


Fig. 4 (Case 1).—Photomicrograph of tumor. High power.

Solitary primary neurogenic sarcoma of the lung occurs rarely. Meade, Kay, and Hughes[13] have reported the surgical removal of one such tumor. In reviewing the literature, no other report of a primary solitary neurogenic sarcoma of the lung was found.

CASE 2.—H. H., a 48-year-old stonemason, was admitted to the Vanderbilt University Hospital on Dec. 12, 1947. One year previously he developed "pneumonia" with cough which was productive of clear, odorless sputum, generalized malaise, fever of unknown degree, and pain in the right chest. He was forced to bed for six months by his illness; during that period of time he lost forty-five pounds in weight in the absence of significant anorexia. He complained of eructation and "gas" which "crowded" his heart. After six months in bed he was able to resume minimal activity but he did not regain his normal strength and weight. Except for the first month of his illness, he had no significant cough and no hemoptysis or wheezing. He continued to complain of abdominal distention and eructation following meals.

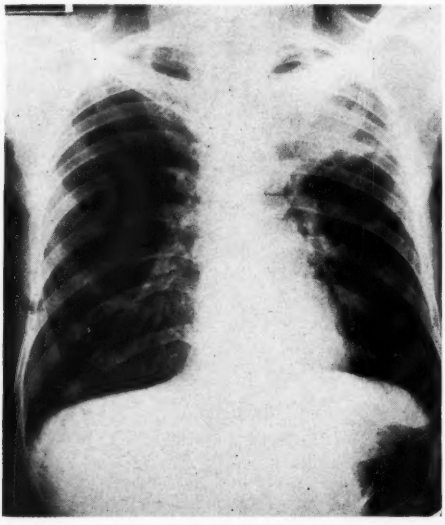


Fig. 5 (Case 2).—Preoperative posteroanterior roentgenogram showing the diffuse density in the left upper lung field.

Physical examination revealed a very poorly nourished, chronically ill colored man of 48 years who was in no acute distress. The skin was loose and dry. There was no lymph node enlargement. The eyes, ears, nose, throat, and neck were normal. There was a moderate degree of dental caries. The thorax showed no deformity. The lungs were clear to percussion and auscultation. The remainder of the physical examination was negative.

Laboratory findings were: urine normal; red blood cells, 2.77 million; white blood cells, 7,350; hemoglobin, 7.0 Gm.; differential count, normal; packed cell-volume, 24 volumes per cent; nonprotein nitrogen, 24 mg. per cent; fasting blood sugar, 8.2 mg. per cent; serum chloride, 100.6 milli-equivalents per liter; total serum protein, 8.22 Gm. per cent (albumin 3.52 Gm./ per cent; globulin 4.70 Gm./ per cent). The stool was positive for bile and negative for occult blood, parasites, and ova. The Frei skin test was positive. Sputum smears contained no acid-fast bacilli.

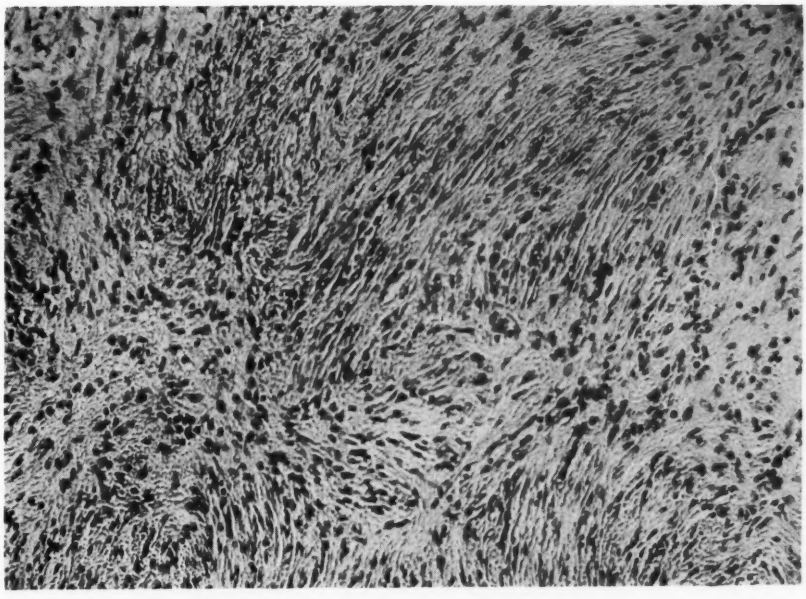


Fig. 6 (Case 2).—Photomicrograph of tumor. Low power.

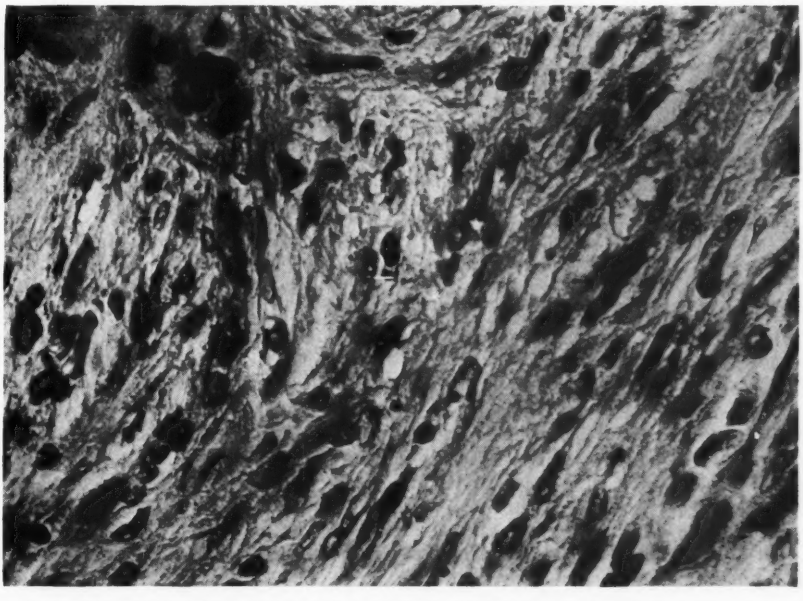


Fig. 7 (Case 2).—Photomicrograph of tumor. High power.

Roentgenograms of the chest showed a homogenous density obscuring the upper one-third of the left lung field; there was a slight shift of the upper mediastinum and trachea to the left (Fig. 5). A gastrointestinal series revealed no abnormality of the gastrointestinal tract.

On bronchoscopy, the left main bronchus was seen to be narrowed and displaced anteriorly and laterally by extrinsic pressure. No intrinsic bronchial lesion was seen. The left main bronchus was partially fixed and the orifice of the left upper lobe bronchus could not be visualized due to distortion of the main bronchus. Bronchial washings were taken for cytologic study and no tumor cells were found.

The impression was probable neoplasm of the left upper lobe.

He was given 1,500 c.c. of whole blood prior to operation.

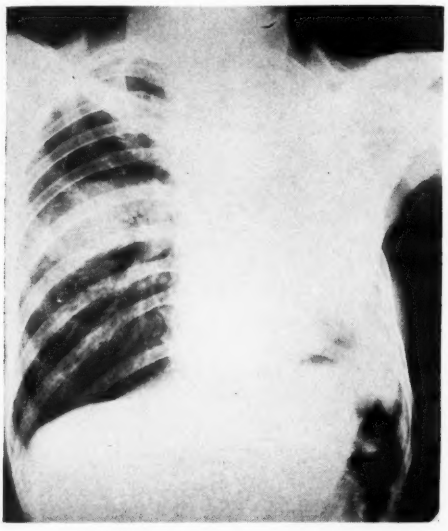


Fig. 8 (Case 2).—Three months following left pneumonectomy. Note the band of density extending from the mediastinum out into the right lung field.

Operation was performed on Jan. 3, 1948, under endotracheal nitrous oxide-oxygen-ether anesthesia. The left chest was entered through a posterolateral incision. A hard tumor mass was found to fill completely the upper lobe, and hard nodules of tumor tissue were felt within the mediastinum. There were dense, fibrous adhesions between the visceral and parietal pleura over the upper lobe; these were divided by sharp dissection. Grossly the tumor had not invaded the visceral pleura over the upper lobe and there was no evidence that the tumor had arisen from the costovertebral gutter. A left pneumonectomy was performed without difficulty.

Examination of the specimen revealed a 5 by 5 by 8 cm. firm mass whose cut surface was grayish white in color and homogenous in consistency. The tumor was quite friable. Microscopically, the tumor consisted of a rather dense connective tissue stroma arranged in whorls of varied types. The tumor cells contained rather scanty cytoplasm; the nuclei varied greatly in size, shape, and staining characteristics. Numerous mitotic figures were present (Figs. 6 and 7). The hilar lymph nodes contained no tumor cells. The diagnosis was neurogenic sarcoma of the lung.

The postoperative course was uncomplicated and he was discharged on the twelfth day to be followed in the Out-Patient Department. He improved slightly during the first

month following discharge then developed progressive dyspnea, wheezing, hoarseness, and weakness. The trachea became deviated sharply to the operative side and this was thought to be perhaps partially responsible for the marked dyspnea. He was readmitted to the hospital three months following operation for further study. There were no new physical findings except for the dyspnea, hoarseness, wheezing, sharp deviation of the trachea to the left, and evidence of further weight loss.

Laryngoscopy showed complete paralysis of the left vocal cord. Roentgenograms of the chest revealed marked displacement of the trachea to the left; the left chest contained fluid and air with a fluid level at the fifth posterior interspace. On the right, there was a rectangular area of density extending out laterally from the hilum across the entire lung field (Fig. 8). This was believed to represent extension of tumor from the mediastinum into the right lung.

The patient was discharged and died at home four months following operation.

SUMMARY

1. Primary solitary neurogenic tumors of the lung have been rarely observed.

2. In a review of the literature, reports of only two such tumors, one benign and one malignant, could be found.

3. Two additional primary solitary neurogenic tumors of the lung, one benign and one malignant, are reported.

REFERENCES

1. Bartlett, J. P., and Adams, W. E.: Solitary Primary Neurogenic Tumor of the Lung, J. THORACIC SURG. **15**: 251, 1946.
2. Blades, B.: Mediastinal Tumors, Ann. Surg. **123**: 749, 1946.
3. Cabot Case No. 22382: Fibrosarcoma of the Lung, Neurogenic, New England J. Med. **215**: 558, 1936.
4. Cutler, E. C., and Gross, R. E.: Neurofibroma and Neurosarcoma of Peripheral Nerves, Arch. Surg. **33**: 733, 1936.
5. Geschikter, C. F.: Tumors of the Peripheral Nerves, Am. J. Cancer **25**: 377, 1935.
6. Harrington, S. W.: Surgical Treatment of Intrathoracic Tumors, Arch. Surg. **19**: 1679, 1929.
7. Heuer, G. J.: The So-Called Hour Glass Tumors of the Spine, Arch. Surg. **18**: 935, 1929.
8. Hosoi, K.: Multiple Neurofibromatosis With Special Reference to Malignant Transformation, Arch. Surg. **22**: 258, 1931.
9. Keller, W. L., and Callender, G. R.: Neurofibroma Arising on the Pericardial Pleura, Ann. Surg. **92**: 666, 1930.
10. Kent, E. M., Blades, B., Valle, A. B., and Graham, E. A.: Intrathoracic Neurogenic Tumors, J. THORACIC SURG. **13**: 116, 1944.
11. Louria, M., and Lederer, M.: Neurofibromatosis With Sarcoma of the Lung, J. THORACIC SURG. **9**: 612, 1940.
12. Maksim, G., Henthorne, J. C., and Allebach, H. K.: Neurofibromatosis With Malignant Thoracic Tumor and Metastasis in Child, Am. J. Dis. Child. **57**: 381, 1939.
13. Meade, R. H., Kay, E. B., and Hughes, F. A.: A Report of 196 Lobectomies Performed at Kennedy General Hospital Chest Surgical Center From 1943 to 1946 With One Death, J. THORACIC SURG. **16**: 16, 1947.
14. Rubin, E. H., and Aronson, W.: Primary Neurofibroma of the Lung, Am. Rev. Tubere. **41**: 801, 1940.
15. Touroff, A. S. W., and Sapin, S. O.: Solitary Intrathoracic Neurofibroma. Surgery **26**: 787, 1949.

LIBRARY
BOSTON UNIVERSITY
SCHOOL OF MEDICINE

ONE HUNDRED THIRTY CONSECUTIVE THORACOPLASTIES

Evaluation of Results in Different Types of Pulmonary Tuberculosis

Poul Ottosen, M.D., Carol Popp, M.D., Mount Vernon, Mo., Arch J. Beatty, M.D., and William W. Buckingham, M.D., Kansas City, Mo.

THE purpose of this paper is to analyze 130 consecutive thoracoplasties performed on 128 patients at the Missouri State Sanatorium from Jan. 1, 1945, to Jan. 1, 1947. This report is an analysis of the early and late results of thoracoplasties performed during a two-year period with a follow-up of from three to four years. The patients were divided into groups according to the predominant clinico-pathologic features of the disease as determined from their clinical records and their chest roentgenograms. The patients are divided into the same six classifications as used by Rubin and Klopstock in a recent report. We have found the classification used by these authors very satisfactory.

At a time when new methods are being used in the treatment of pulmonary tuberculosis and older methods are being abandoned, it is our hope that this paper will result in clarifying the indications and contraindications for thoracoplasty and other surgical procedures including pulmonary resection.

MATERIAL

In the two-year period from Jan. 1, 1945, to Jan. 1, 1947, a total of 128 patients with pulmonary tuberculosis were treated with 130 thoracoplasties. Seventy-seven were females, fifty-one were males.

One hundred twenty-four were white, four were Negroes. The youngest patient operated on was 16 years of age. The oldest patient was 64 years of age. The average age was 34.8 years.

Thoracoplasties performed for tuberculous empyemas were excluded from this series. All patients were sputum positive for acid-fast bacilli preoperatively. Pulmonary functional tests were limited to studies of the vital capacity before surgery. We are fully aware of the inadequacy of this method to obtain a true picture of the pulmonary function, but no other tests were available at that time. Electrocardiograms were done routinely before surgery. None of the patients received streptomycin therapy before or during surgery, since this drug was not available in large amounts at the time the thoracoplasties were performed. The technique of the thoracoplasties was uniform throughout this series, as all were performed or closely supervised by one surgeon (W. W. B.). The operation was the modern type multistaged, posterolateral, extrapleural thoracoplasty. In the majority of cases the interval between stages was two to three weeks. A total of 302 stages were performed. One hundred ninety-one stages were done under nitrous oxide anesthesia. One hundred eleven stages were done under epidural anesthesia.

Received for publication Aug. 21, 1950.

CLASSIFICATION

As mentioned, our 130 cases were divided into six groups using the same classification as Rubin and Klopstock with only slight modifications.

Group I.—

Fibro-caseous Tuberculosis: Active disease had not existed for more than two years. The lesions were predominately of the productive type with cavities less than four centimeters in diameter, and not more than one-third of the lung was involved.

Group II.—

Fibroid Tuberculosis: The disease had existed for many years and not less than two years. The pulmonary disease was of the fibrosclerotic type with marked retraction of the involved lobe or lobes. Rigid cavities not more than four centimeters in diameter were present in most of these cases.

Group III.—

Caseocavernous Tuberculosis: Patients with a definite progressive caseating type of tuberculosis are included in this group.

Group IV.—

Giant Cavities: Patients with cavities larger than four centimeters in diameter were included in this group.

Multiple cavities were occasionally present. Cavities of both the tension and nontension variety are included in this group, and a large percentage of the cavities occupied an entire lobe.

Group V.—

Destroyed Lung: This group consists of patients with tuberculosis throughout the entire lung often associated with upper lobe fibroid tuberculosis and tuberculous or nontuberculous bronchiectasis throughout the lung. Basal cavities were occasionally present in this group.

Group VI.—

Unexpandable Lung: Patients in this group had been treated with pneumothorax which had resulted in an unexpandable lung, and thoracoplasty was performed to obliterate the pleural space.

Table I shows the distribution of the cases according to the classifications mentioned above. The status of the contralateral lung at the time of operation is also listed in this table.

Fifty-six patients (43.1 per cent) had no disease or inactive disease in the contralateral lung, whereas 32 patients (24.6 per cent) had active uncontrolled disease at the time of operation. Forty-two patients had active disease treated with pneumothorax or pneumoperitoneum. Thirty-six patients (26.1 per cent) had pneumothorax and 8 patients (6.2 per cent) had pneumoperitoneum in order to control active disease in the contralateral lung.

From these figures it is evident that the material consists of rather poor risk patients.

RESULTS OF ENTIRE SERIES

We have divided our results as to early and late. Early results are based on the status of the patients three months after their last stage was completed. At that time all patients had extensive sputum studies for acid-fast bacilli and roentgenologic examination of the chest. This arbitrary time is set because we do not think that examination at an earlier date would enable us to evaluate the thoracoplasty results. Furthermore, we feel that if positive sputum for acid-fast bacilli or residual cavitation are present three months after the last stage, a revision thoracoplasty can still be helpful to these patients.

TABLE I

	NUMBER CASES	CONTRALATERAL LUNG			
		NO DISEASE	INACTIVE DISEASE	ACTIVE UNCONTROLLED	INACTIVE CONTROLLED WITH PNX. OR PERITONEUM
I. Fibrocaseous	37	10	8	5	14
II. Fibroid	20	3	6	4	7
III. Caseocavernous	17	3	4	8	2
IV. Giant Cavity	42	2	15	13	12
V. Destroyed Lung	13	1	4	2	6
VI. Unexpandable Lung	1	0	0	0	1
Total	130	19	37	32	42

Early results were classified as (a) successes, (b) failures, and (c) deaths. The operation was considered successful when (1) cavity closure was obtained as determined by "overexposure technique" or laminographs, and (2) sputum examinations were negative for tubercle bacilli by smear, culture, or guinea pig inoculation. Any case with positive sputum for acid-fast bacilli and/or residual cavitation was considered a failure. Cases in which it was not possible to complete the thoracoplasty because of cardiorespiratory failure, spreads, reactivations, or for some other reason are also listed as failures.

From Fig. 1 it is seen that cavity closure and sputum conversion for acid-fast bacilli were obtained in seventy-two patients (56.2 per cent). Forty-nine patients (38.3 per cent) were considered as failures. Seven patients died within the first three months after their last stage thoracoplasty. All deaths that occurred within the first three months following the last stage thoracoplasty are considered as operative deaths. Thus the operative mortality was 5.5 per cent.

Table II lists the seven postoperative fatalities as well as the seventeen late fatalities.

POSTOPERATIVE COMPLICATIONS

The most serious postoperative complications observed were spreads. Spreads were observed in five patients (3.8 per cent) within the first three months after the last operative stage. Three of these patients received nitrous oxide-oxygen anesthesia; two patients received high epidural anesthesia. There were no postoperative reactivations.

TABLE II. FATALITIES, OPERATIVE AND LATE

Postoperative Deaths	
Cardiorespiratory insufficiency	6
Diabetic Coma	1
Total	7 (5.5%)
Late Deaths	
Cardiorespiratory insufficiency (Two had pneumonectomy following thoracoplasty)	10
Progressive Pulmonary Tuberculosis	4
Unknown Reason	2
Bronchogenic Carcinoma in Operative Side. (Both pulmonary tuberculosis and carcinoma verified by autopsy)	1
Total	17 (14.9%)

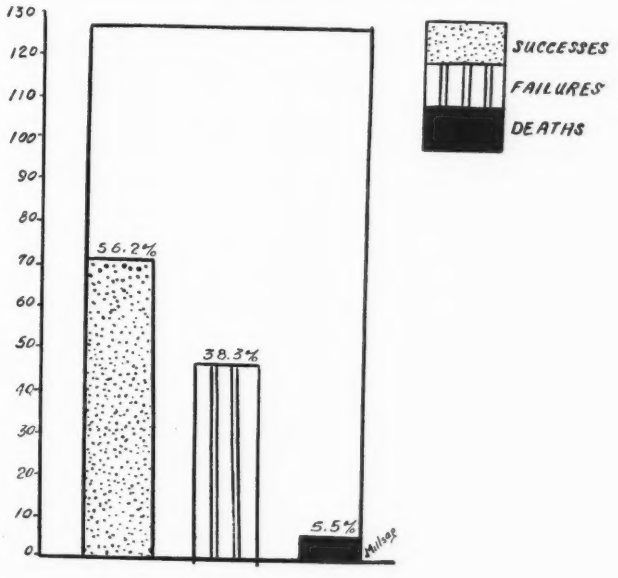


Fig. 1.

In one case a tuberculous empyema developed in the operative side. One patient had a spontaneous pneumothorax in the contralateral side a few days following surgery. This patient died. Four patients had secondary wound infections.

LATE RESULTS

In a recent investigation of the present condition of the 128 patients, we were able to trace 121 (94.5 per cent). The investigation was carried out by sending questionnaires to all patients who were discharged from the sanatorium. A large majority of the patients we were able to trace had had recent chest roentgenograms and sputum examinations for acid-fast bacilli at the outpatient department of the Missouri State Sanatorium. The condition of those patients

who had been followed somewhere else were judged from reports made by their private physicians or by the institutions where chest roentgenograms and sputum examinations for acid-fast bacilli had been made. The patients who were followed were divided into three categories: (1) arrested tuberculosis, (2) active tuberculosis, and (3) dead. All patients who had arrested tuberculosis from an x-ray standpoint and also had negative sputum examinations for acid-fast bacilli were considered well, even if they were not working. Patients who still had active tuberculosis as judged from their chest roentgenograms or had positive sputum examinations for acid-fast bacilli were considered still sick. The National Tuberculosis Association's classification was used to distinguish between active and arrested tuberculosis.

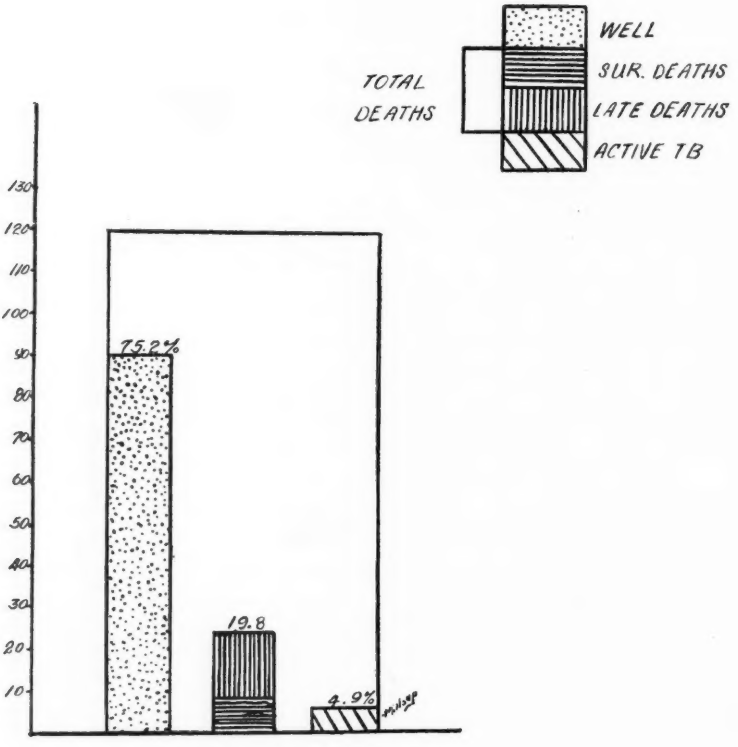


Fig. 2.

As shown in Fig. 2, ninety-one patients (75.2 per cent) of one hundred twenty-one patients followed were arrested. Seventeen patients (13.2 per cent) died more than three months after the last stage of thoracoplasty. These seventeen fatalities are listed in Table II. The over-all mortality was twenty-four deaths (19.9 per cent). Six patients (4.9 per cent) still have active tuberculosis.

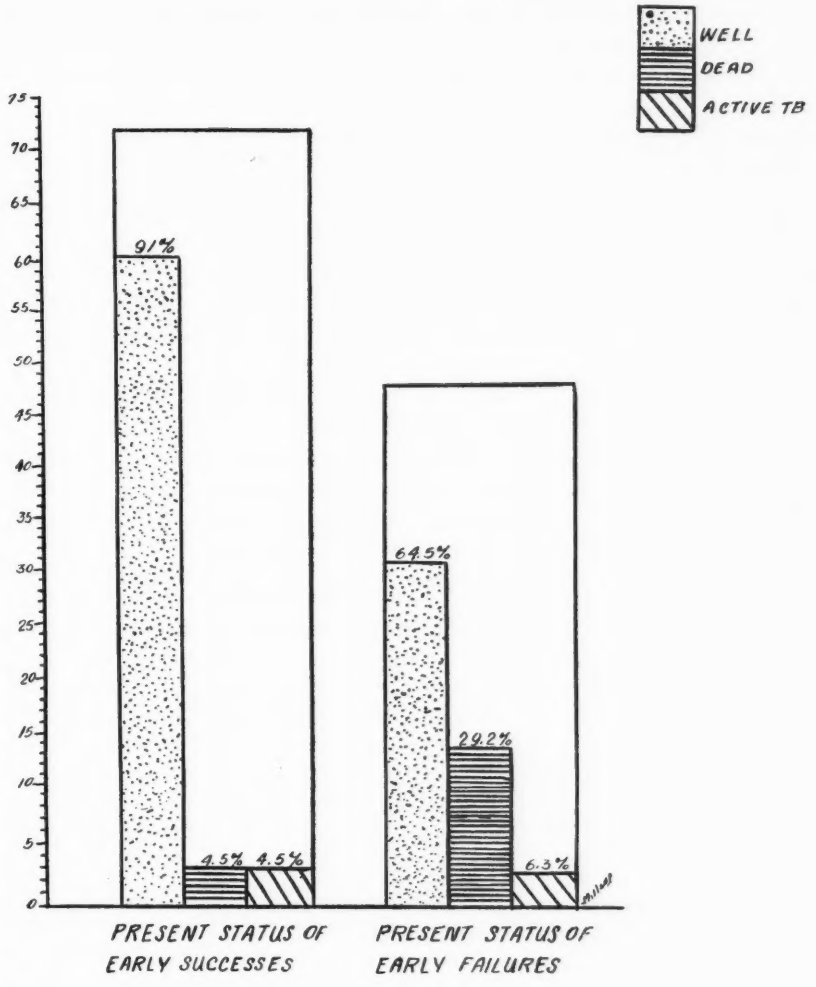


Fig. 3.

THE FATE OF EARLY FAILURES AND EARLY SUCCESSES

In order to evaluate the importance of early failures and early successes, we have compared the late results in these two groups. Table V shows the present status of the forty-nine patients who were considered as early failures and the seventy-two patients considered as early successes. The fate of the forty-nine* patients with early surgical failure is rather poor as compared to the fate of the seventy-two patients with early surgical success. Fourteen

* No follow-up on one of these patients, leaving a total of 48 on whom follow-ups were obtained.

patients (29.2 per cent) of the forty-eight cases of early failures followed are dead, whereas only three patients (4.5 per cent of the early successful cases are dead at the present time. Thirty-one (64.5 per cent) of the early failures are considered arrested cases as compared to sixty (91.0 per cent) arrested cases in the group of early successes. Therefore patients with positive sputum for acid-fast bacilli and/or residual cavitation three months after the completed thoracoplasty have a definitely poorer prognosis than the patients with sputum conversion for acid-fast bacilli and cavity closure at that time. Whenever a patient who has undergone thoracoplasty is still positive for acid-fast bacilli three to six months following the last stage, every effort to convert the sputum should be undertaken. If a revision thoracoplasty has already been performed, a lobectomy or pneumonectomy should be considered at this early date following the last stage of thoracoplasty.

LATE RESULTS IN DIFFERENT CLINICO-PATHOLOGIC GROUPS

Group I.—

Fibrocaseous Tuberculosis: Thirty-five patients were found to have tuberculosis of this type. Two patients had bilateral thoracoplasty within the period studied. Thus thirty-seven thoracoplasties were performed for fibrocaseous tuberculosis. This group includes lesions predominantly productive in type associated with small or medium-sized cavities. No patient in this group had progressive lesions. This type of tuberculosis is considered an ideal indication for thoracoplasty when the contralateral lung is free of disease or has inactive disease. However, in five patients active disease was present in the contralateral lung, and fourteen patients had active disease in the contralateral lung controlled with either pneumothorax or pneumoperitoneum. Therefore, even in this most suitable group of patients, the conditions were far from ideal. Thirty-four patients were followed. The fate of the patients followed is seen in the first column in Fig. 4. Thirty-one patients (91.6 per cent are alive and well. One patient (2.8 per cent still has active tuberculosis, and two patients (5.6 per cent) are dead.

Group II.—

Fibrosclerotic Tuberculosis: This type of disease has existed for many years, and not less than two years. The lesion is predominantly fibrosclerotic associated with small rigid-walled cavities. Fibrosclerotic tuberculosis represents the late stage of fibrocaseous disease. Usually there is marked retraction of the diseased part of the lung with the mediastinum and hilus pulled toward the diseased area. Compensatory emphysema is often present in the surrounding "healthy" lung tissue. Twenty patients were included in this group. The second column in Fig. 4 shows the fate of the nineteen patients followed. Eighteen patients (94.7 per cent) are alive and well. One patient (5.3 per cent) still has active tuberculosis. It will be noted that there were no postoperative or late deaths in this group.

Group III.—

Caseocavernous Tuberculosis: Patients with a progressive type of tuberculosis were included in this group. As a rule these patients are not suitable for

any type of collapse therapy. The prognosis with as well as without treatment was considered rather poor until the antibiotics were introduced and the majority of the patients in this group should be considered as salvage cases, not only because of the progressive lesions in the operative side, but also because of active disease in the contralateral side (See Table I). Nevertheless, we have submitted seventeen such patients to thoracoplasty in the two-year period studied. We were able to follow fifteen patients, and column three in Fig. 4 shows their present status. Eleven patients (73.4 per cent) are well. One patient (6.6 per cent) still has active tuberculosis. Three patients (20 per cent) have died.

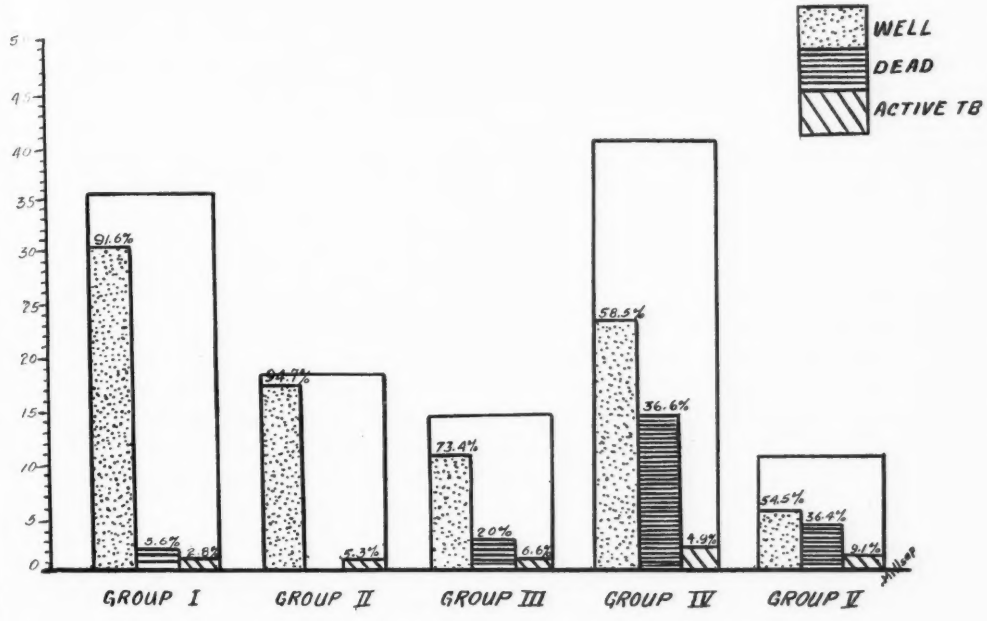


Fig. 4.

Group IV.—

Giant Cavities: The main feature in the chest roentgenogram of patients included in this group is a cavity larger than four centimeters in diameter. A majority had cavities larger than that; some had cavities occupying an entire lobe. A distinction between tension and nontension cavities has not been attempted because intracavity pressure readings (which is the only accurate way of making a distinction between these two types of cavities) were not performed. However, there is no doubt that the majority of all cases with giant cavitation, from a roentgenological standpoint, had tension cavities at least at some time during the period prior to surgery. Of the forty-two patients in this group,

only one could not be followed. The fate of the forty-two patients followed is seen in column four in Fig. 4. Twenty-four patients (58.5 per cent) are alive and well. The over-all mortality showed fifteen deaths (36.6 per cent). Two patients (4.9 per cent) still have active disease.

Group V.—

Destroyed Lung: Tuberculosis was usually present throughout the entire lung with cavities in both upper and lower lobes. Bronchiectasis of specific and/or nonspecific types were visualized in the majority of these patients preoperatively. In some cases compensatory emphysema was present. Fibrotic tissue and/or atelectasis within the lung often caused the mediastinum to be shifted toward the diseased side. Thirteen patients were included in this group. column five in Fig. 4 shows the fate of the eleven patients that we were able to follow. Six patients (54.5 per cent) are alive and well. The over-all mortality was four deaths (36.4 per cent). One patient (9.1 per cent) still has active tuberculosis.

Group VI.—

Unexpandable Lung: Only one case was listed in this group, and the present status of this patient is unknown.

CONCLUSIONS

Good late results were obtained in Groups I and II. The good results in Group II are in contrast to what could be expected and also in contrast to the results of Rubin and Klopstock. Group III shows surprisingly good results when the status of the contralateral lung is taken into consideration. Groups IV and V show the poorest results, and most of our failures and deaths fall into these two groups. Therefore it is our belief that the treatment of choice for patients classified in the first three groups is thoracoplasty. It is still a matter of discussion if thoracoplasty or resection should be performed on patients belonging to Groups IV and V.

SUMMARY

An analysis has been made of 130 consecutive thoracoplasties on one hundred twenty-eight patients with pulmonary tuberculosis.

The cases are divided into six groups according to clinico-pathologic characteristics. Our purpose of this study is to evaluate the late results with thoracoplasty in the different groups. Another purpose is to evaluate the importance of early success, and early failure, and compare the late results in these two groups.

The present status of the entire series is as follows: Of the 128 patients, we were able to trace 121 patients (94.5 per cent). Seventy-five and two-tenths per cent of the patients have arrested tuberculosis, 4.9 per cent of the patients still have active tuberculosis. The operative mortality was 5.5 per cent. The over-all mortality was 19.9 per cent.

Group IV, giant cavities, and Group V, destroyed lung, account for most of the fatalities, whereas good results were accomplished in Group I, fibrocaseous

tuberculosis, and Group II, fibroid tuberculosis. Group III, caseocavernous tuberculosis, showed fairly good results when treated with thoracoplasty.

We are still undecided as to whether patients with giant cavities and destroyed lung should be treated with thoracoplasty or resection. At present, we are comparing thoracoplasty results with resection results in these types of pulmonary tuberculosis, but as yet our material is too limited to draw definite conclusions.

The present status of early successful thoracoplasties are compared with the present status of thoracoplasties considered as early failures. Ninety-one per cent of the early successful cases are well, and 9 per cent are either dead, or have active tuberculosis. Sixty-five per cent of the early thoracoplasty failures are well, whereas 35 per cent are dead or have active tuberculosis at the present time.

REFERENCE

1. Rubin, M., and Klopstock, R.: Influence of Type of Disease on the Results of Thoracoplasty in Pulmonary Tuberculosis, Am. Rev. Tuberc. 60: 273, 1949.

ACCESSORY DIAPHRAGM

A Case Report

Thomas B. Sappington, Jr., M.D., and Rollin A. Daniel, Jr., M.D.,
Nashville, Tenn.

THE failure of complete formation of the diaphragm, which results in diaphragmatic hernia, is not unusual. The most frequent congenital abnormalities are hernias through the pleuroperitoneal canal (the foramen of Bochdalek), the abnormally large esophageal hiatus, and the subcostosternal foramen (Larrey's space or the foramen of Morgagni).

Casey and Hidden[1] have reported the failure of development of the central tendon of the diaphragm, found at autopsy in a newborn infant. This resulted in a free pericardioperitoneal communication. A somewhat similar case, in an adult, had been previously reported by Martland.[2]

Drake and Lynch[3] have recently reported a very unusual abnormality in a 24-year-old man with bronchiectasis of the right lower lobe. The diseased portion of the lobe was found to be "trapped" by an extra leaf of the diaphragm which arose from the dome of the normal diaphragm. This extra leaf formed a "backpocket" which enclosed a portion of the right lower lobe, and the two parts of the lobe were connected posteromesially through the aperture in this extra leaf.

We have encountered a very unusal anomaly of the diaphragm. We are unable to find a description of a similar case reported in the literature.

CASE REPORT

The patient, a 7-year-old white girl, first entered Vanderbilt University Hospital on Jan. 28, 1949. She had had a severe upper respiratory infection a month before admission. This was followed by persistent cough, productive of a tablespoonful of clear mucoid sputum daily. She also had had several small hemoptyses. There was no history of aspiration of a foreign body. Examination revealed slight tracheal shift to the right. There was dullness to percussion and depressed breath sounds in the right lower lobe posteriorly and laterally. No râles were heard. The cardiac impulse was shifted almost to the midline. Fluoroscopy revealed a marked mediastinal shift to the right. Roentgenograms revealed a hazy area of increased density which occupied the right lower anterior thorax which was thought to represent atelectasis of the middle lobe. Bronchoscopy showed a large amount of thick, mucoid sputum in the bronchi of the right lung. All major bronchi were patent, and no foreign body was seen.

The patient was readmitted to Vanderbilt University Hospital on May 19, 1950. She had been asymptomatic during the interval. Physical examination revealed a well-developed, well-nourished, intelligent young girl in no acute distress. The trachea was shifted moderately toward the right. The left lung was clear. There was a dull percussion note below the sixth rib posteriorly and laterally on the right. The right base did not descend on in-

From the Department of Surgery, Vanderbilt University School of Medicine.
Received for publication Aug. 28, 1950.

spiration. The breath sounds were depressed over this same area, and numerous fine râles could be heard laterally at the seventh interspace. Fluoroscopic examination and roentgenogram of the chest revealed persistent mediastinal shift toward the right (Fig. 1).

The above changes were interpreted as being due to atelectasis of the right middle or lower lobe, the cause being obscure.

Operation.—On May 20, 1950, the right pleural cavity was opened posterolaterally through the seventh intercostal space. It was immediately apparent that an "accessory diaphragm" was present. One diaphragm was in its normal location, and was without defects. However, it appeared to be almost devoid of muscle and to consist largely of fascia covered by pleura. This diaphragm contracted very little on inspiration. The accessory or upper diaphragm was attached anteriorly to the pericardium and central tendon. It then arched posteriorly at the level of the fifth rib and ended near the angle of the rib. Near the pericardium was an aperture in which the hilar structures to the right lower lobe were situated. This hiatus was about four centimeters in diameter. Thus, the right lower lobe occupied a compartment of its own, separating it from the right upper lobe (Fig. 2).

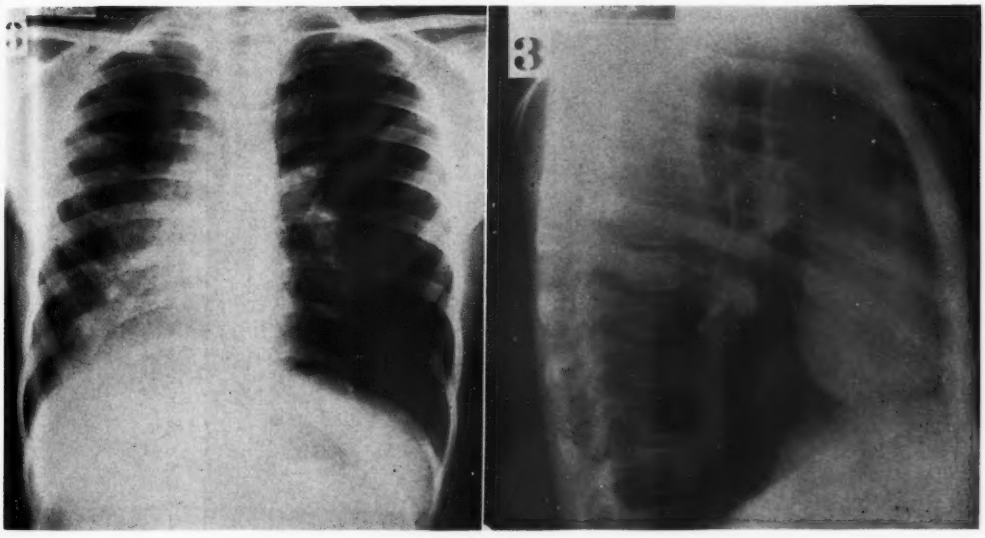


Fig. 1.—Preoperative roentgenogram of chest.

The accessory diaphragm was excised, leaving a narrow linear defect in the parietal pleura. Branches of the phrenic nerve were demonstrated to enter both the accessory and the normally placed diaphragms. Stimulation of the phrenic nerve produced vigorous contraction of the muscular, accessory diaphragm, while contraction of the normally situated diaphragm was feeble.

After excision of the accessory diaphragm, the right lung was inflated. Both the upper and lower lobes were grossly normal and were inflated readily. The right middle lobe could not be demonstrated as a separate lobe; it appeared to be represented by a small fingerlike projection which was separated from the upper lobe by an incomplete fissure.

The chest wall was closed in layers with interrupted fine silk sutures without drainage. The patient's postoperative course was uncomplicated. She was discharged from the hospital on the seventh postoperative day.

Fig. 2.—Artist's conception of accessory diaphragm before and during removal.

Roentgenogram of the chest two months after operation (Fig. 3) revealed the mediastinum to have shifted to some extent toward its normal position. Fluoroscopy showed very slight motion of the right diaphragm.

DISCUSSION

It appears that this patient presents an incomplete descent of the septum transversum. According to Arey,[4] the septum transversum of the 2-millimeter embyro occupies a position high in the cervical region. It then enters a relative caudal migration. This migration is irregular in that the ventral portion of the septum shifts more rapidly. After the 5-millimeter stage, the reverse is true.

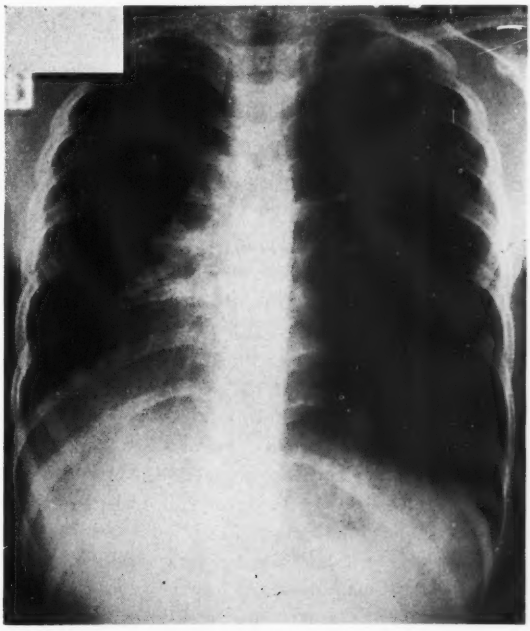


Fig. 3.—Roentgenogram made two months after operation.

When opposite the fifth cervical segment, the septum receives its innervation from the phrenic nerve. At about this level, the septum acquires muscle primordia, probably from neighboring cervical myotomes. These migrate caudally with the septum and aid in diaphragmatic development.

The lung buds are formed at about the 4-millimeter stage, when the septum transversum is located at about the third or fourth cervical segment. The ventral portion of the septum is then more caudad than the dorsal part. It seems plausible that during this stage of development the lung bud on the right grew into the septum transversum so as to split it into two parts. The accessory diaphragm could thus have been prevented from entering into the formation of the normally located diaphragm due to the fact that the cells of the lung bud forming

the right lower lobe of the lung developed below this portion of the septum. The remaining portion of the septum transversum underwent a normal descent to enter into the formation of the normally placed diaphragm with the pleuroperitoneal membrane and the somatic musculature of this region. In the case reported here, the major portion of the muscle mass was left above in the accessory diaphragm at the level of the fifth dorsal segment.

The aperture between the accessory diaphragm and the pericardium, through which the hilum of the lower lobe extended, was small enough that intermittent, partial obstruction of the lower lobe bronchus may have occurred. Furthermore, the hiatus may not have increased in size with progressive growth of the child and the enlargement of the hilar structures of the lower lobe.

REFERENCES

1. Casey, A. E., and Hidden, Eleanor H.: Nondevelopment of the Septum Transversum, Arch. Path. **38**: 370, 1944.
2. Martland, H. S.: A Case of Congenital False Diaphragmatic Hernia, J. A. M. A. **52**: 1574, 1909.
3. Drake, E. H., and Lynch, J. P.: Bronchiectasis Associated With Anomaly of the Right Pulmonary Vein and Right Diaphragm, J. THORACIC SURG. **19**: 433, 1950.
4. Arey, L. B.: Developmental Anatomy, Philadelphia, 1934, W. B. Saunders Company, p. 230.